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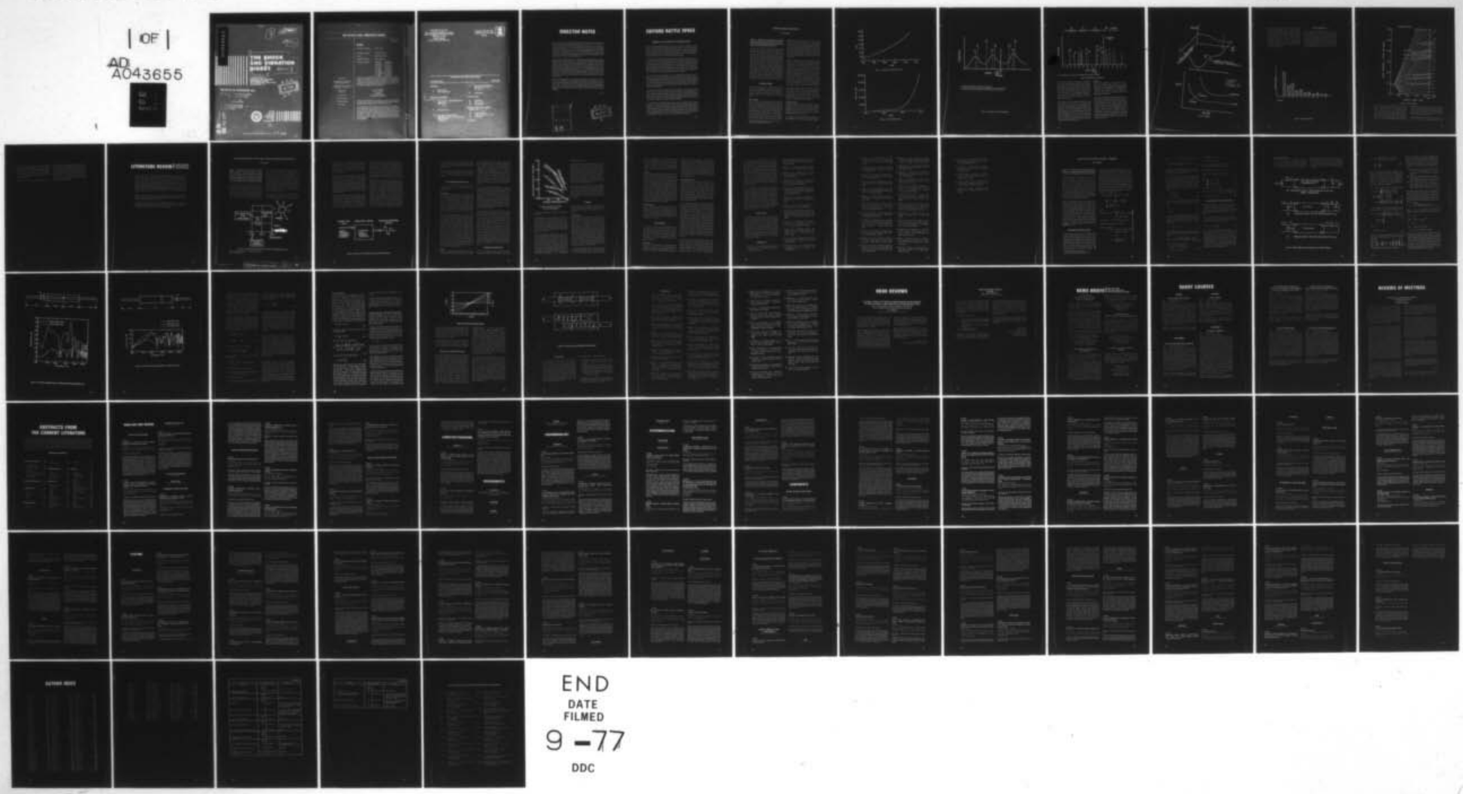

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THE SHOCK AND VIBRATION DIGEST

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THE SHOCK AND VIBRATION DIGEST

VOLUME 9 No. 8 August 1977

DIRECTOR NOTES

On previous occasions I have discussed information centers and some of the factors that contribute to the effectiveness of their operation. This month I would like to point out that an information center manager must always keep in mind the character and composition of his user population. Like most centers, SVIC operates on a homogeneous level, that is, the users are themselves generators of technical information. Furthermore, there is a significant differentiation among groups within the user community. To be most useful the collection of technical information must be analyzed and disseminated in a way that is understandable by and applicable to the needs of each of these groups.

SVIC users cover a wide range -- from "pure" research scientists to applied analysts, design and test engineers. Those in the forefront of basic research usually need less assistance than the experimentalists or design engineers. This latter group includes all the "project" types who must move rapidly from one problem to another without the luxury of being able to develop their own background information for the problem at hand. Neither do they have the time to understand fully how a given method or technique was developed; yet they must be sure that their approach to the problem uses the best technique available at that time. This is not to imply that these are not innovative people, for this type of problem solving involves creativity at its best. It is to this group, however, that an information center should be of greatest service.

There is a noticeable lack of comprehensive "applications" information in a form that is easily collectable. If one examines this DIGEST, for example, he will note that most review articles are from academic sources. The reason for this is the same "time factor" mentioned in the previous paragraph. We must encourage design and test engineers to document the new methods developed to solve their special problems and to participate in the review process that will significantly help their colleagues.

H.C.P.

EDITORS RATTLE SPACE

AMERICA'S VOLUNTARY STANDARDS SYSTEM

America's voluntary standards system could be in for drastic changes in the near future. The American National Standards Institute (ANSI), a nonprofit corporation founded in 1918, believes that the proposed federal "Voluntary Standards and Accreditation Act of 1977" (S.825) would decimate the ranks of voluntary participants who develop national standards. My continuing interest in national and international standards prompts me to review this important issue.

The enactment of S.825 would change the process of standards development, and it is not yet clear to me whether federal coordination and promulgation will enhance or detract from current standards activity. In my opinion, the most important question is whether or not currently active volunteers will be interested in working for a government-regulated standards activity. The strength of the existing U.S. standards system lies in the thousands of technical people who have willingly given their time free-of-charge for standards work. This important work has thus been carried out without cost by eminently qualified technical people.

The U.S. Congress was motivated to introduce legislation that would place U.S. standards activity under federal control as a result of several instances in which the current system was misused. However, in view of the fact that 25,000 standards have been developed through ANSI, which has minimal resources for management and control, the overall record is a good one. In my opinion, the number of cases of abuse will not decrease because the federal government decrees the formation of still another bureaucracy.

The voluntary standards system does not need regulation and control; rather it needs resources to carry out the peripheral work that a volunteer-based system cannot provide. Volunteer standards activity has often progressed slowly because funds are not available for editing, typing, and translating. Lack of travel funds is also a problem. Funds for peripheral work would make the volunteer system more efficient and increase the number of standards developed.

If the proposed federally-controlled system can be conducted with minimum regulation -- that is, if the system can continue to operate through technical organizations in the provate sector with funds provided for publication and travel -- I believe S.825 will work. If the federal program is replete with red tape, it will not work, and the voluntary standards work force will be no more. If this happens, the U.S. standards program will be less effective than it is today. The key to a good standards program is to keep the voluntary technical effort going!

R.L.E.

TURBOMACHINERY VIBRATION

J.F. Traexler*

Abstract - This article is concerned with turbomachinery vibrations, particularly those that occur in large steam turbines at central station power plants. Rotor dynamics and blading are reviewed.

Interest in the vibration of steam turbines has been due primarily to the fact that 80% to 90% of the problems involve vibration. The continuing effort to develop more power per pound of metal and the extremely high cost associated with forced outages point up the importance of preventing vibrations. The marked increase in power level (see Fig. 1) has not, for the most part, been accompanied by a corresponding increase in the size of steam turbines because of the increase in power developed per pound of metal. However, as designs have approached the physical limits of materials, vibration problems have increased. The cost of a one-day outage at a large plant can be as high as half a million dollars (see Fig. 2) clearly a strong incentive for eliminating vibration problems. The first section of this review deals with rotor dynamics, the second with blading.

ROTOR DYNAMICS

The areas of concern in rotor dynamics include the prediction and assessment of critical speeds, both lateral and torsional; the prediction and analysis of vibratory response levels; and the evaluation of stability limits and the consequences of exceeding them.

Critical Speeds

Both methods of calculation and philosophy of lateral critical speeds have changed in the past 25 years. In the early 1950s it was common practice to assume rigid supports at the bearings and to treat one span at a time in the model. Calculations were made graphically or numerically. The objective of critical speed determinations was to avoid having a running speed at a critical speed -- in other words, each span was "tuned" to avoid certain frequencies. It was recognized that large discrepancies existed between calculations and tests, and efforts were made to improve the analyses. The rigid supports were replaced by elastic springs with stiffness equal to that of the oil film in the bearings. In addition, the advent of the high-speed digital computer made more complete analyses possible. Later, it was recognized that entire systems, rather than single spans, should be analyzed. After entire systems were studied, it became clear that a change in philosophy was required.

Figure 3 illustrates journal response versus the ratio of natural frequency to running speed. R_1 and R_2 indicate the rigid support calculations which, of course, give natural frequencies or critical speeds, not response. E_1, E_2, and E_3 show the bearings treated as elastic springs and are not in terms of response. A_1, A_2, and A_3 are the actual critical speeds as measured by the peaks in the tested response characteristic. It can be seen that critical speeds based on rigid support calculations can be seriously in error; that critical speeds calculated assuming elastic supports can be more accurate; and that neither calculation can be used to determine a response level because damping has been neglected.

Figure 4 shows an analysis of a complete system: high pressure turbine, intermediate pressure turbine, low pressure turbine, generator, and exciter. Assuming elastic supports at the bearing, 22 critical speeds between zero and the running speed were calculated. With such a large spectrum of natural frequencies, tuning has limited application.

Vibration Response

A reasonable design procedure is to require that the response of the rotor when in operation is within acceptable bounds. A rotor running smoothly at 3,600 RPM has a double amplitude of whirl at the journals of 2 mils or less. The value in a machine running roughly is 4 mils or more.

The change in design philosophy with regard to lateral vibration of rotors has thus involved a switch

*Westinghouse Electric Corporation, Steam Turbine Div., Lester Branch, Philadelphia, PA 19113

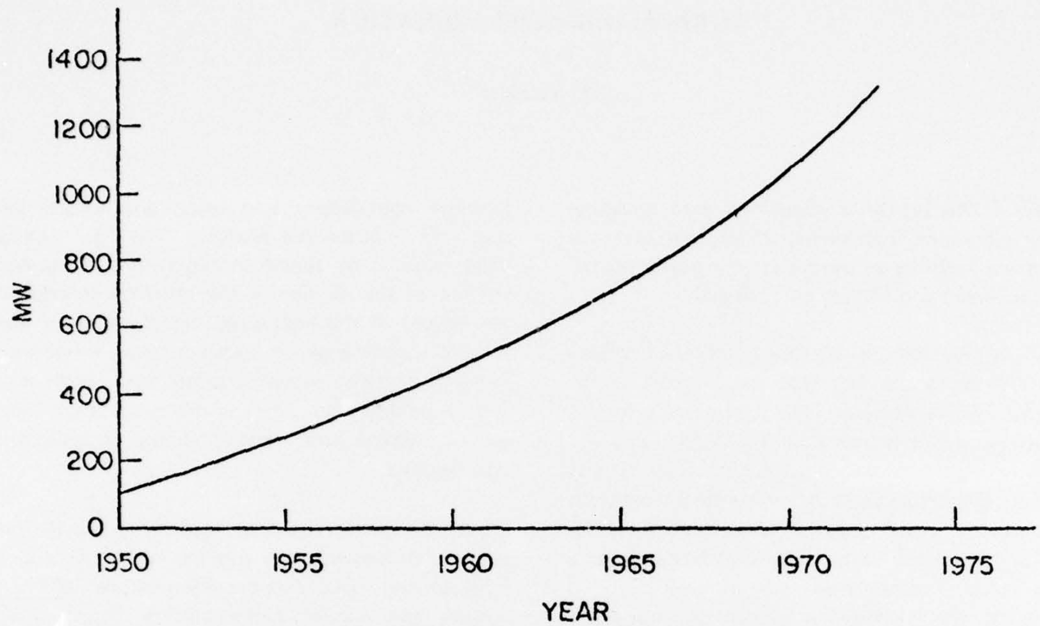


Figure 1. Largest Steam Turbines in Service

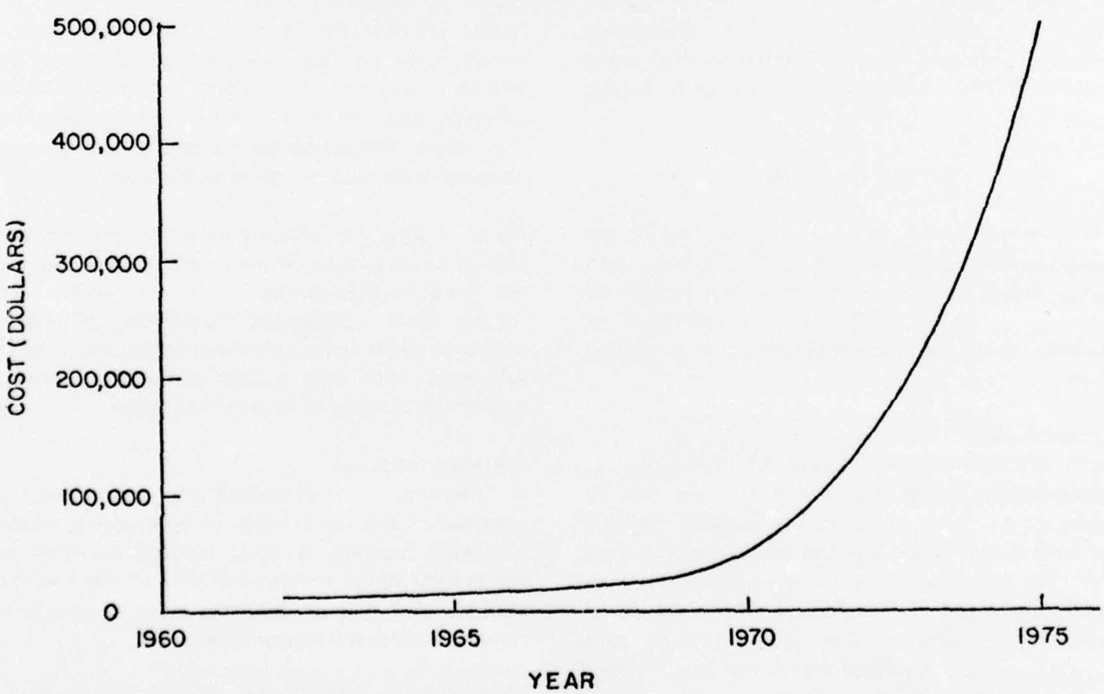
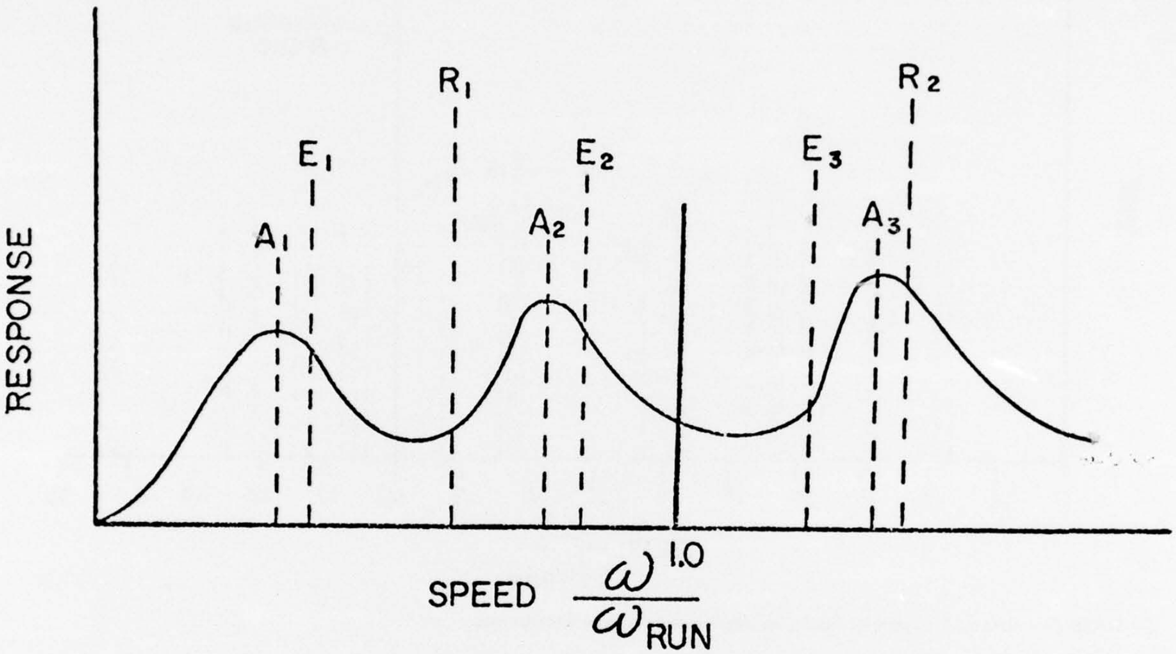
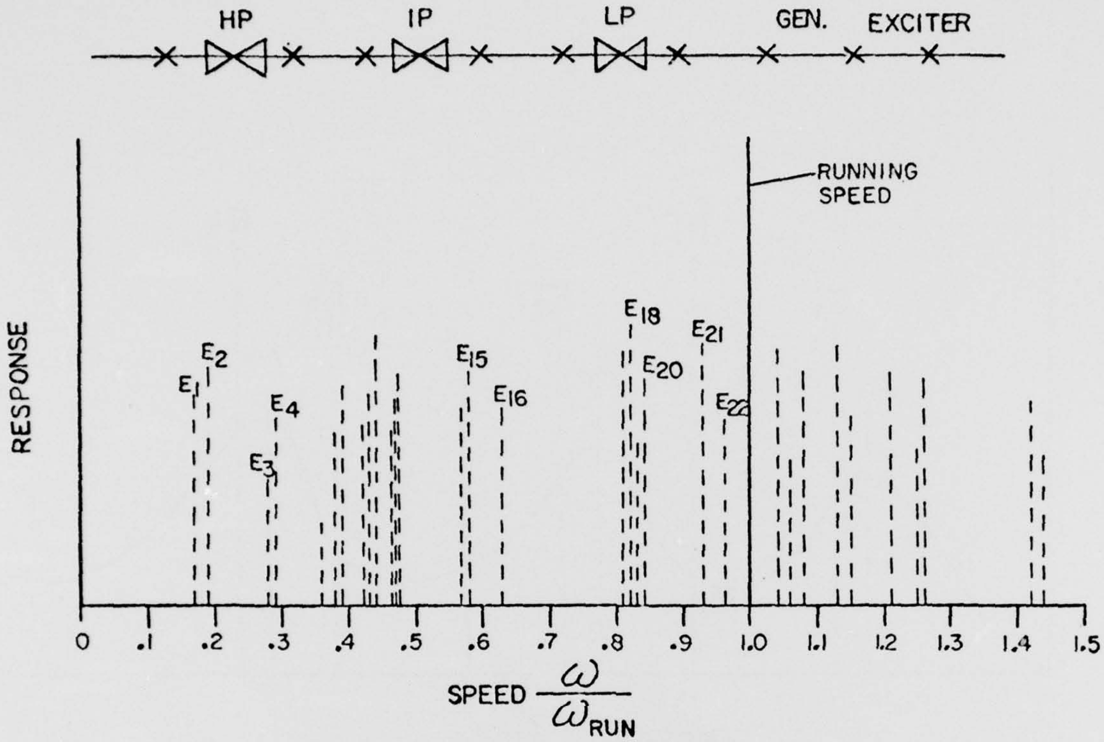


Figure 2. Cost of One Day Outage



R = Rigid Bearing Undamped Lateral Natural Frequencies
E = Undamped Lateral Natural Frequencies Including Bearing and Pedestal Flexibilities
A = Unbalance Response Including Bearing and Pedestal Flexibility and Damping

Figure 3. Single-Span Lateral Critical Speeds



E = Undamped Natural Frequencies Including Bearing and Pedestal Flexibilities

Figure 4. Multi-Span Critical Speeds

from tuning to response. At present, a simulation technique is used for calculations, and rotor designs are accepted or rejected on the basis of the response at the journals as a function of running speed. Figure 5 illustrates the acceptance criterion. Journal amplitude is used only as an index; the exact failure mode is not yet known. In all probability, excessive response would result in bearing failures or perhaps in loss of the bearing caps. Fortunately, few such failures have occurred.

In contrast to lateral vibration, torsional natural frequencies are tuned to avoid coincidence with running speed and known exciting frequencies. The problem in torsional oscillations involves blade/rotor interactions. It is sometimes possible to excite blade bending vibrations with torsional oscillations of the rotor. Methods now exist for accurately predicting torsional frequencies of rotors; these methods account for blading. Tuning can be used in design because torsional damping is slight and relatively few torsional natural frequencies exist.

Stability

With regard to stability in rotor dynamics, the designer is concerned with predicting the stability threshold and with evaluating the consequences of operating in the unstable region. He is specifically concerned with whether or not the instability is bounded; numerical time marching techniques are generally used in analyses.

A great deal of theoretical and experimental work has been done for individual bearings and simple two-bearing systems. As in the case of lateral vibration, the real problem involves multi-span systems. Field experience has shown that theoretical predictions for oil whip, which is a type of hydrodynamic bearing instability, generally predict instability before it actually occurs. Figure 6 is a stability chart; the Summerfeld number is the abscissa. Thus, although theory correctly predicts trends and overall behavior, significant discrepancies between theory and actual experience do exist.

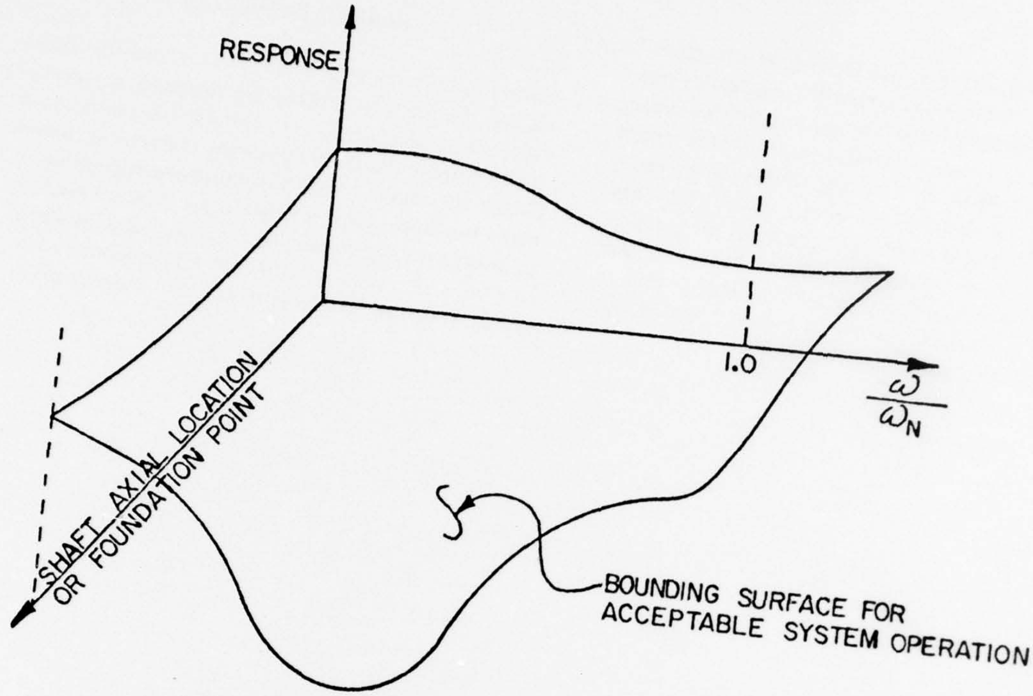


Figure 5. Multi-Span Response to a Simulated System Unbalance

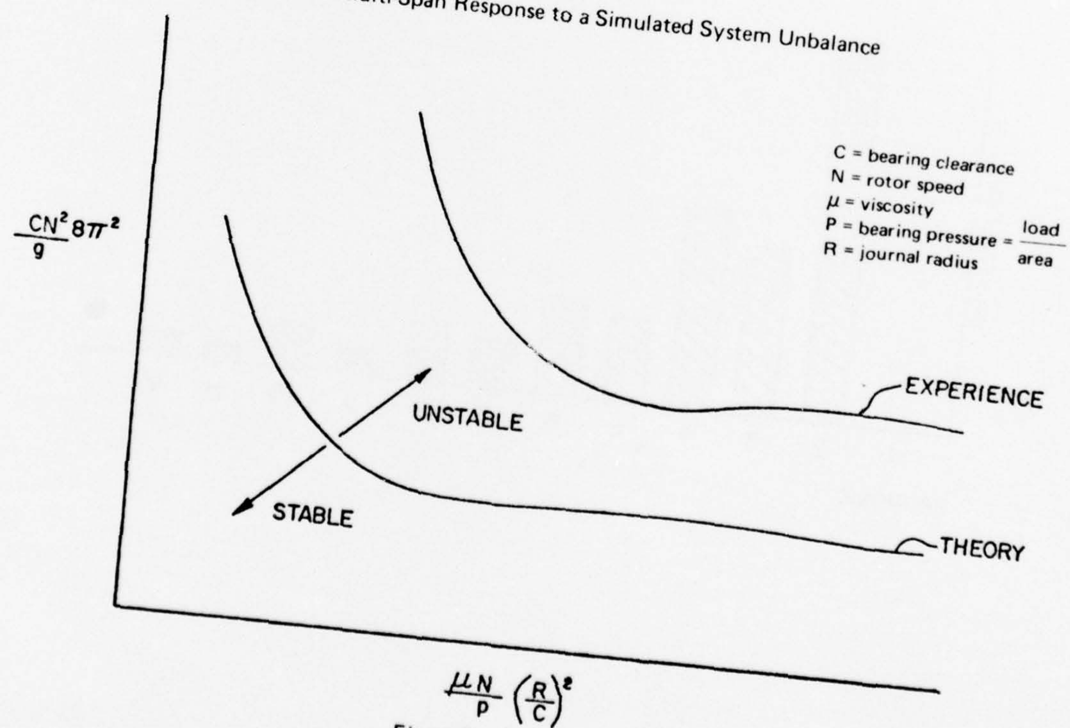


Figure 6. Stability

Another instability that has received much attention is known as rotor whirl. From the mechanics standpoint it is similar to the bearing instabilities already mentioned and can be treated with similar procedures. Much work is currently underway to verify theoretical predictions of rotor whirl. To date, problems involving rotor whirl have, in the author's experience, been solved by simple changes in seal clearances and alignment of seals to shafts. Rotors of stiffer construction than in the past should not experience rotor whirl.

BLADE VIBRATIONS

Some turbomachinery blades are tuned to avoid certain frequencies; others are designed to survive resonance that might occur. The last rows of modern steam turbine blades are generally designed as tuned blades; the reason is that it is physically impossible to make the blades large enough in the chord dimension to survive resonance (see Fig. 7). The energy available to excite vibrations is shown as a function of a harmonic, which is the integer multiple of running speed.

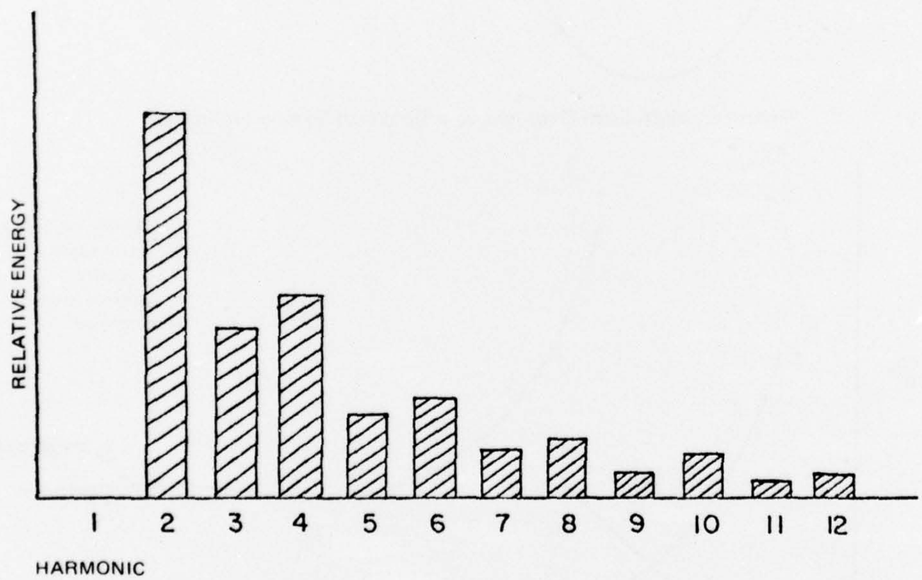


Figure 7. Harmonic Excitation

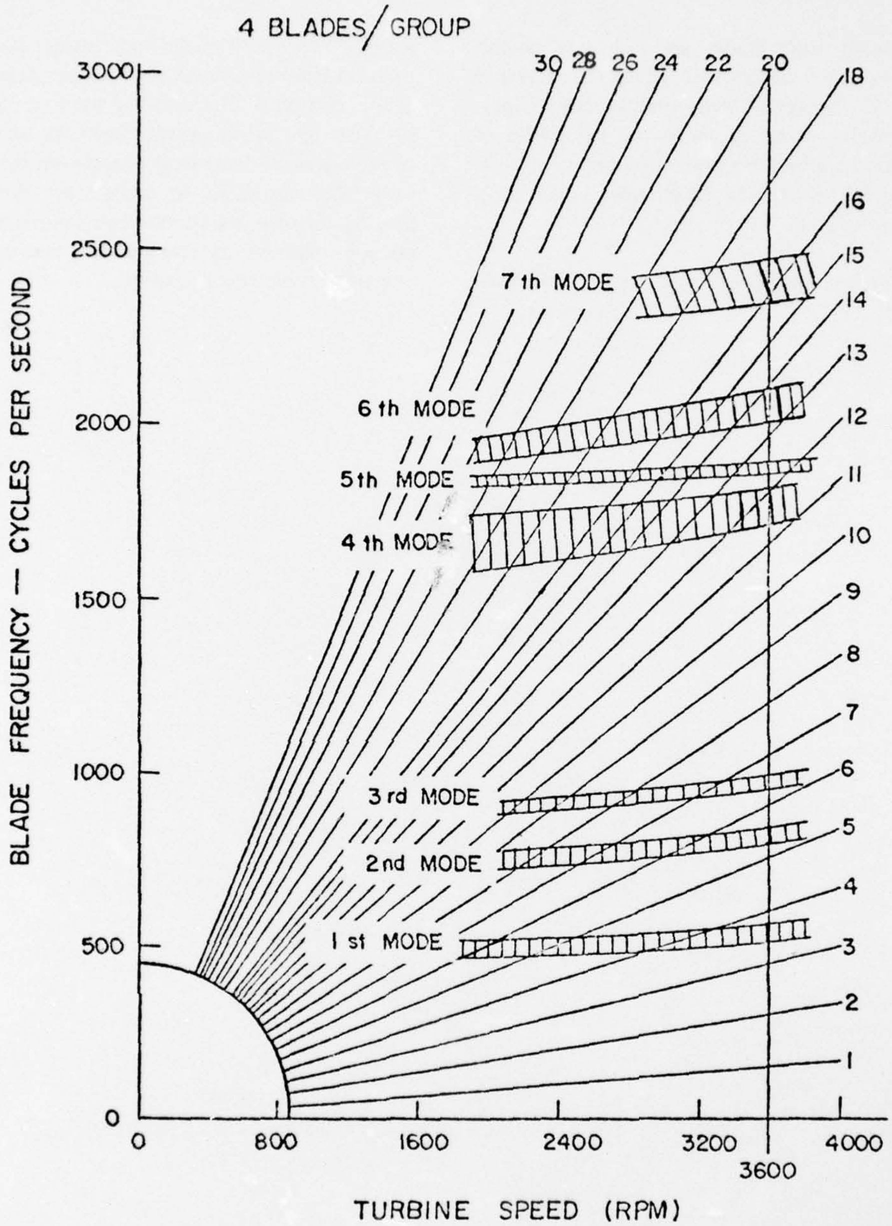


Figure 8. Campbell Diagram

The general trend is such that more energy is available in the lower harmonics at which the longer blades operate. Figure 8 is a Campbell diagram (a plot of blade frequency versus running speed) for the next-to-last row of a 3,600-RPM machine. It can be seen that the three lower modes are tuned -- that is, their natural frequencies do not coincide with a harmonic of running speed. Modes above the three fundamental ones are tuned in some cases and not in others. The blades are designed so that they will survive resonance at these modes. The bands shown for each mode result from minor geometric variations and preclude tuning for higher modes.

Untuned blades comprise about 80% of those used in a steam turbine. The design is based on past

experience; that such blades are presently among the most reliable components of steam turbines speaks well for the use of these designs. Blade vibration problems are most severe in the last stages of modern turbines, where transonic flows and extremely high loadings are present. Much work is currently underway in this area.

Blading and rotor dynamic problems associated with steam turbines are somewhat similar: tuning is used to avoid vibrations when possible; otherwise, response is the criterion. The method used is based on experience and continuously shifts as more data become available. Statistical procedures based on past experience are used in both rotor dynamics and blading. Careful, well-documented experimental studies are required to complement the sophisticated analytical tools now available.

LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

Review articles by H.S. Ward on "The Characteristics of Dynamic Loads and Response of Buildings" and by M.L. Munjal on "Exhaust Noise and Its Control" are contained in this issue of the DIGEST.

Structural dynamic problems involving buildings are covered in Dr. Ward's article along with environmental disturbances. In Dr. Munjal's article recent developments in the analysis and design of exhaust mufflers are reviewed.

THE CHARACTERISTICS OF DYNAMIC LOADS AND RESPONSE OF BUILDINGS

H. S. Ward*

Abstract - This paper is concerned with structural dynamic problems involving buildings. Ground-borne disturbances including earthquakes, nuclear explosions, construction activities and vehicular traffic are discussed. Air-borne disturbances including wind and overpressures due to explosions are reviewed. Finally, thermal loads are included in the paper.

This is the first in a series of review articles on structural dynamic problems involving buildings. In these articles the word building includes those structures that are the usual concern of civil and structural engineers. Because it is difficult to distinguish between loads that should be called dynamic and those that are static, some of the data presented in the series might seem more relevant to static loads. In the past only a few engineers have had to confront the difficulties associated with predicting the action of dynamic loads on buildings. Nevertheless, a significant amount of pertinent information exists in the technical literature, stretching back over a period of at least 50 years. This first review is mainly concerned with some of this earlier work. A number of factors suggest that engineers will be now and in the future more involved with structural dynamic problems; subsequent reviews will deal with information that is likely to be of use in keeping abreast of the problems and their solutions.

The sources of some of the dynamic loads that act on buildings are summarized in Figure 1, which refers to land-based structures. It can be seen that

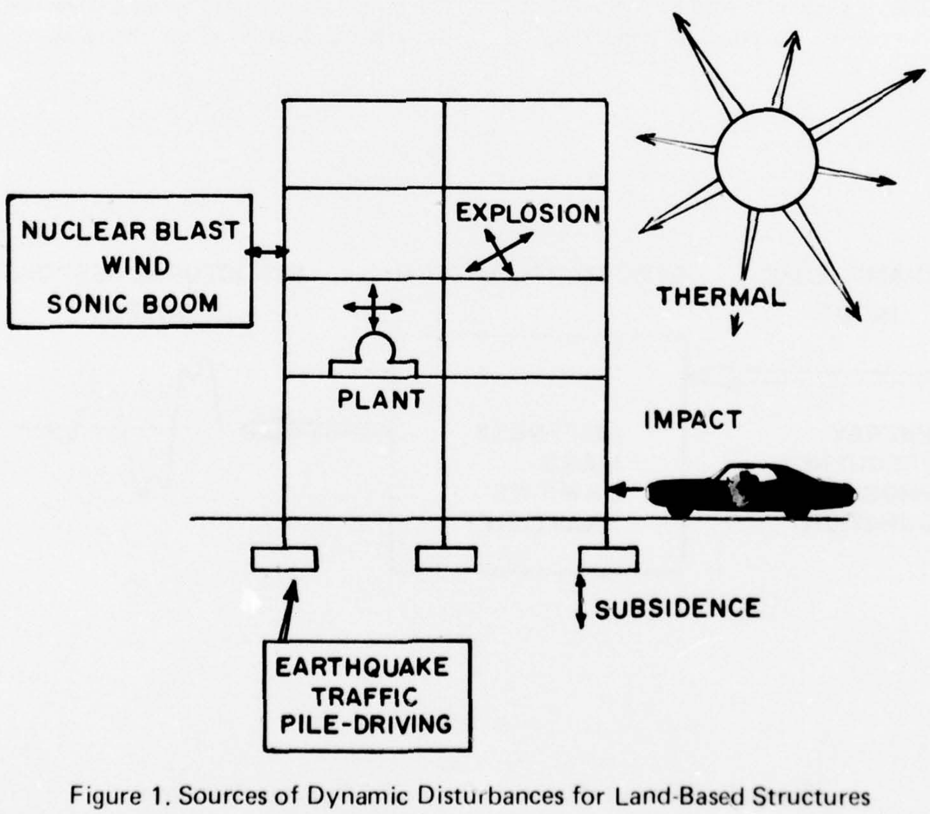


Figure 1. Sources of Dynamic Disturbances for Land-Based Structures

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Plymouth PL4 8AA, UK

both man-made and naturally-occurring dynamic disturbances occur. The effect of earthquakes has perhaps received the most attention in the past. Economic pressures and disturbing social developments, however, might make other loads of prime concern in the future.

Economic pressures are producing a situation in which structures are becoming both lighter and larger -- and thus more susceptible to the action of such loads as wind. Small groups of people in both developed and developing countries practice anarchy, which is frequently manifested in attempts to destroy buildings. In such cases, the primary concern of the engineer must be to minimize hazards to human life, rather than to preserve property, but the two factors are closely linked.

The so-called energy crisis sparked a dramatic increase worldwide in the search for offshore fuel reserves. The exploration of the North Sea revealed shortcomings in our knowledge of this hostile environment. It can be argued that, if the problems of a growing world population are to be contained, the demand on engineers to design a wider range of structures for use in the sea will increase. Such structures would house and feed men, as well as provide energy and material. A prerequisite for these developments is a better understanding of the action on structures of wave loads; tidal, turbidity, and ocean currents; and icebergs; as well as such environmental factors as corrosion. In the short term this information can be obtained only by measuring the performance of existing structures in the sea.

The designer of a building must usually predict its response to a number of loading conditions. This complex process is represented by the simple diagram of Figure 2, in which the load is an input to the "black-box" representing the building; the output of the system represents structural response. Characteristics of the dynamic load that are of particular interest include energy content as a function of frequency and probability of occurrence. If the stiffness, mass, and damping of the structural system produce natural frequencies of vibration within the range of those with the most energy in the input, large structural responses will develop. This will be the central issue in these review articles. Unfortunately it is not possible to use theoretical concepts to

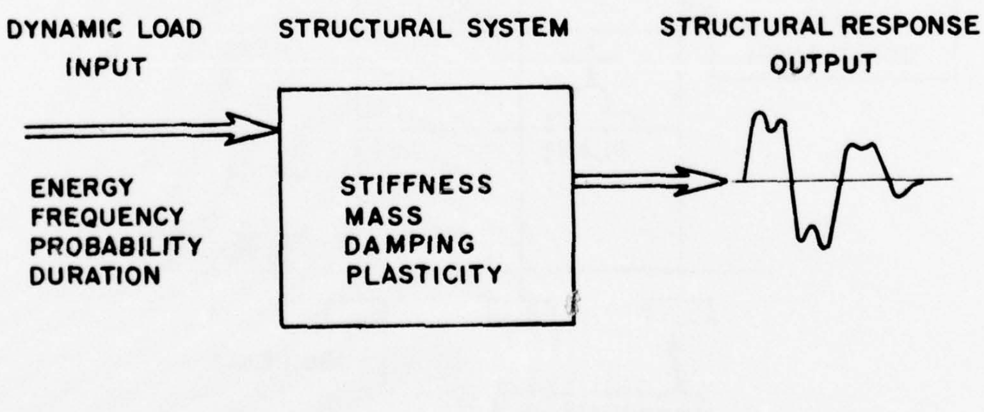

Figure 2. Factors Influencing Structural Dynamic Responses

provide the designer with necessary data. The response of existing structures to a particular dynamic load should be measured to assess the characteristics of the load [1].

This review presents information on dynamic loads, considers methods that have been used to measure structural responses, and deals with field measurements.

GROUND-BORNE DISTURBANCES

Ground-borne disturbances include earthquakes, nuclear explosions, construction activities, and vehicular traffic.

Earthquakes

UNESCO has estimated that, each year between 1925 and 1950, earthquakes caused, on the average, the loss of 14,000 lives and 400 million dollars worth of damage to buildings throughout the world. In the past 12 months, a series of severe earthquakes have served to highlight the severity of this type of dynamic loading on structures. Most of the knowledge related to the characteristics of earthquakes and their effects on buildings has come from bitter experiences and hard-earned lessons over the past 40 years.

Building code regulations are rarely up to date; many earthquake load regulations nevertheless reflect awareness of earthquake effects [2]. Three of the most significant factors in modern codes are seismic regionalization [3], a procedure for calculating the dynamic response of structures [4], and some consideration of the ground-structure interaction phenomenon [5]. In effect, seismic regionalization allows for the probable recurrence of a large earthquake. The other two factors attempt to allow for the interaction of the frequency content of the ground motion and the dynamic characteristics of the structural system. Earthquake engineering provided the impetus for recent work in soil dynamics [6], a topic that will have much wider application in the future. An early, but very useful, source of references related to earthquake-resistant design has been provided by Rosenbiueth [7].

Others

Nuclear explosions are being considered as a way to excavate large quantities of soil. Such use of nuclear power has resulted in the removal of some data from classified-secret files of defense organizations [8]. Theoretical methods for predicting ground motion levels and frequency content produced by underground nuclear explosions are not yet well established. The development of such methods is dependent upon actual measured data [9, 10]. The results of the Boxcar underground explosion, which had a yield of 1.2 megatons, showed that peak particle velocities of around 0.2 cm/sec were produced at a range of 1×10^4 meters; most of the energy was within the frequency range of 0.25 to 1.0 Hz.

The Suffield Research Establishment in Alberta, Canada, carries out much of the serious work in the Western world on large conventional explosions. The results are probably of limited interest to civil engineers, however [11]. More useful results have been obtained from the study of quarry blasts or controlled explosions, in which interest has centered on the vibration levels that produce damage to buildings [12, 13]. European and North American investigations have suggested that structural particle velocities of around 3 cm/sec will produce damage in masonry and concrete walls [14, 15].

Construction activity and vehicular traffic also cause dynamic disturbances of buildings. Some pertinent information has been summarized [1] and is reproduced in Figure 3. The blasting data have been scaled to represent the effect of a one pound charge. In the case of traffic vibrations the riding surface of the road has the greatest influence on the level of the ground motion that is generated. It is of interest that dynamic loads are not always a source of nuisance, as exemplified by the piling data. The sonic pile driver creates less disturbance when producing a resonant driving force in the pile-ground system than do conventional systems. Most of the energy content (frequency) of these disturbances lies between 0.5 and 50 Hz. Measurements of the dynamic loads on 30 highway bridges in the United Kingdom [16] are representative of the useful design data that can be obtained from full-scale testing of structures.

AIR-BORNE DISTURBANCES

Air-borne disturbances include wind and those resulting from explosions. The characteristics of wind

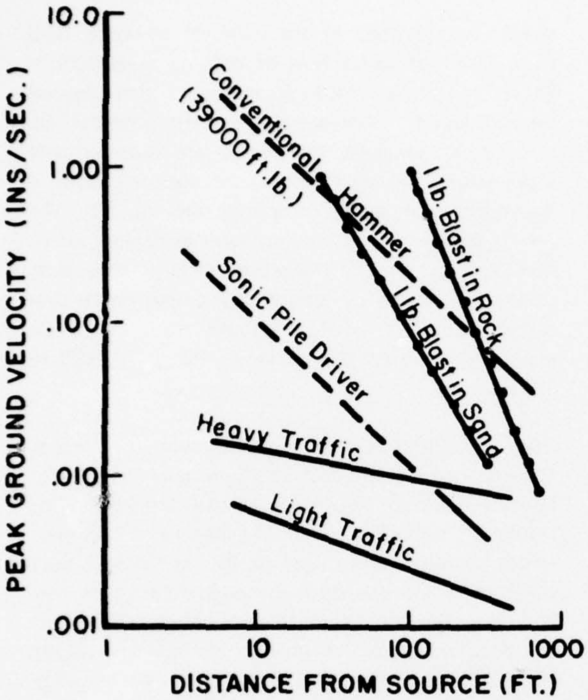

Figure 3. Attenuation of Some Ground Disturbances

loading have already been the subject of a literature review [17].

The detonation of nuclear weapons in the air produces N-shaped pressure transients with peak overpressures that are functions of the distance from ground zero and the yield of the weapon. A one megaton explosion would cause an overpressure of 1,000 lb/in^2 at a range of 1,000 yd and 1 lb/in^2 at 10,000 yd. The positive phase of the pressure transient would be about two seconds.

Powerful explosives, if detonated in an open space, produce shock waves that travel about 1,000 m/sec. The decrease of peak pressures is approximately equal to the square of the distance from the source. For example, a one kilogram charge of TNT would develop a peak pressure of around two atmospheres at a range of one meter; the positive phase of the overpressure would last about one millisecond [18]. The shock wave following explosions within an enclosed space undergoes a number of reflections; a considerable magnification of the corresponding free-air pressure can occur.

In gaseous explosions, including explosions of dust suspensions, the atmospheric oxygen needed to support the combustion process tends to produce a slower build-up in pressure than that generated by powerful explosives. The upper limit to the peak pressure that can be developed even by confined gaseous explosions appears to be around 100 lb/in^2. This pressure is difficult to achieve in practice because the relative slowness of the combustion process allows vents to blow out at low pressures; the result is a reduction in the final pressure.

Sonic booms are another form of dynamic loading that might become significant to the civil and structural engineer. At present it seems unlikely that the problems will be difficult to solve [19]. For example, normal operations of the British-French plane the Concorde can be expected to produce overpressures of 2.5 lb/ft^2.

OTHERS

Other types of dynamic loading of structures include thermal loads due to temperature variations and fire, impacts, and the action of ocean waves, currents, and wind.

Thermal Loads

Daily and seasonal variations of temperature can generate significant movements in large structures. These movements, like those associated with ground settlement or steady-state wind pressure, take place slowly and can be measured in years. The effects would usually be considered to be static loading effects; they are included in this review because the resultant movements can be measured only with advanced instrumentation derived from dynamic test methods. An important design problem in temperature movements involves multistory buildings -- exterior and interior columns can be subjected to temperature differences in excess of 100° F. Most of the work on this problem has been carried out by structural engineers responsible for designing the tallest buildings in North America [20].

Fire loads constitute a dynamic loading, insofar as the temperature increases that occur can be measured in minutes. Observations have shown that a wide

range of fire loads can occur, depending upon the type of building and its contents. These factors complicate the selection of appropriate fire resistance for any structural component. Survey data from disastrous events can provide useful information about the real loads that develop in structures [21].

Impacts

Steam-driven rail engines experienced the first type of impact loading dealt with by structural engineers. The effect of the "hammer blow" on railway bridges was compensated for by adding about ten percent to the known weight of the train. Potential sources of impact loading now include aircraft and massive trucks. The possible hazards of such loadings should not be dismissed because they rarely occur. On at least one occasion a threat was made to fly a large aircraft into a nuclear power station. In addition, some modern load-bearing masonry buildings would suffer extensive damage if they were hit by a truck. Data on measured and estimated loadings due to the impacts of heavy vehicles and aircraft [22] could be used as the starting point for design of structures that withstand the action of such loads.

Offshore Loads

Most of the loads that must be considered in the design of offshore structures are dynamic -- the action of waves, winds, and currents. Engineers will probably become increasingly involved with the construction of structures in the sea; valuable data are already available [22 - 24] and will be described in the next article in the series.

MEASUREMENT

One reason for the lack of useful data pertaining to structural dynamics of structures is that too few civil engineers are familiar with modern instrumentation. Many experiments involving dynamic loading have been prompted by the devastating effects of earthquakes on tall buildings. The laser is gaining in importance as a tool for measuring large slowly varying movements.

Techniques

Perhaps the greatest obstacle to the accumulation of data on the nature of dynamic loads acting on buildings has been a lack of knowledge among civil engineers of modern instrumentation techniques. Until all professional engineers in the construction industry have been made aware of available instrumentation, it is unlikely that the quantity of experimental data needed to improve theoretical concepts will increase. Some information about appropriate measuring techniques for structural dynamics has been published: a survey of instrumentation provides the uninitiated with necessary vocabulary [25], and other papers deal with new ideas that may be needed in the future [26, 27].

Structural Movements

Measurements of structural movements have been made by using either naturally-occurring or man-made dynamic forces. The most frequently used sources of excitation have been wind and earthquakes. One of the earliest experiments was the attempt to measure the movements of the Empire State Building in New York City [28]. A long pendulum was suspended in the fire tower, and both wind- and temperature-induced drifts were recorded. Similar indirect measurements have involved recording structural strains [29].

A considerable amount of work during the 1960s was aimed at determining the natural periods of vibration for tall buildings. A more rational approach to designing such structures so they can withstand the effects of earthquakes provided the stimulus for these investigations. In most cases, electro-mechanical seismographs or accelerometers were used to measure the dynamic movements. The Japanese used a forced vibration test technique [30]; a wind-induced test method was later perfected in Canada [31] after original work had been done by the U.S. Coast and Geodetic Survey. Another group based at California Institute of Technology obtained information about the significance of the ground-structure interaction phenomenon [32]. Most of the measurements in all of these investigations involved horizontal movements in tall buildings; accelerations rarely exceeded gravity and occurred in a frequency range of 0.1 to 20 Hz.

Temperature effects and wind loads produce large slowly varying movements that are difficult to measure. A number of recent developments utilize optical methods; it is likely that the laser will also play a significant role in overcoming some of these problems [26, 27, 33]. Although movements can exceed a meter or more, the time required ranges

to months or even years. Movements of more than 15 cm were recorded over a 24 hour period for a guyed tower at Cedar Hill, Texas, as a consequence of wind effects. Crude measuring equipment has been used to record thermal movements in a number of buildings in the Chicago area [34]; results suggested that columns could move as much as 0.1 cm per story when the exterior temperature was around - 20°C. Far more experimental data are needed with regard to temperature and wind movements of buildings. Surveying and photogrammetry are two approaches that might also be used [35, 36], but they do not generate information in a form that can be easily analyzed.

Except in the case of earthquakes, the structural movements created by most dynamic loads do not produce significant damage to the main frame. Glazing and partitions are usually damaged; the damage associated with wind loads has recently been reviewed [37]. Another criterion that must be seriously considered is the response of people to structural movements, particularly if the frequencies are much below 1 Hz [38, 39]. Recent conferences and symposia provide a comprehensive range of papers that extend the source of references for dynamic loading of structures [40 - 42].

CONCLUSIONS

The influence of dynamic forces on structures did not arouse widespread interest until recently. Economic pressures and technical developments are changing this position, however, and as structures become lighter and safety factors are lowered, problems that arise must be dealt with properly. Far more experimental work must be performed to obtain data on both the characteristics of the forces and the movements they produce in existing buildings. Proper understanding of this information would allow designers to approach the design of new buildings with greater confidence.

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EXHAUST NOISE AND ITS CONTROL - A REVIEW

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Abstract - This article describes recent developments in the field of analysis and design of exhaust mufflers. The article is concerned only with exhaust noise.

Automotive engines are responsible for most of the noise that pollutes the environment of cities. A recent survey shows that, even though heavy commercial trucks comprise only 0.5% of the vehicle population, they account for 17% of the noise [1]. Heavy trucks are the noisiest, with motor cycles a close second; passenger cars and light trucks are less noisy. One reason commercial trucks are noisy is their low horse power-to-weight ratio, which requires them to operate at or near full power during acceleration and steady-state operation. Passenger cars rarely achieve high engine speeds [2].

Most automotive noise occurs during the exhaust, intake, and combustion steps of the engine cycle; the cooling fan is also a noise source. Exhaust noise is at least 20 decibels (dB) higher than any other noise in a reciprocating engine [1], with the exception of heavy-duty truck engines, in which combustion-induced engine-body noise -- also called combustion noise, structural noise, or simply engine noise -- is of the same order. Research on the noise generated by the engine block of diesel engines has resulted in semi-empirical expressions for various types of diesel engines [3]. A state-of-the-art review of the analysis and design of exhaust mufflers was published in the **DIGEST** in 1973 [4].

RADIATION OF EXHAUST NOISE

A reciprocating internal-combustion engine discharges hot gases during the exhaust stroke, when the piston moves in with a varying velocity, and pressure in the cylinder drops considerably. This exhaust pattern is repeated with each revolution or every other revolution, depending on whether the engine has a two-stroke or a four-stroke cycle. If N denotes revolutions per minute of the crankshaft, either N or N/2 exhaust pulses occur per minute per cylinder. This periodic pulse is considerably altered as it passes through the exhaust system (consisting of exhaust manifold and exhaust pipe), muffler, and tail pipe. At the end of the tail pipe, the exhaust interacts with the atmosphere to produce sound by means of the monopole mechanism. Until recently, the sound level was calculated by performing a Fourier analysis of the pulse, calculating the sound power associated with each harmonic component, and adding the contributions of all harmonics to determine the sound power radiated out of the tail pipe. The sound power associated with each harmonic component is calculated from equation (3).

$$W^{(n)} = \frac{1}{\rho_o} \overline{p^{(n)} v^{(n)}} = \frac{1}{2\rho_o} P^{(n)} . V^{(n)} \cos \phi^{(n)}$$

$$= \frac{1}{2\rho_o} P^{(n)} \cdot \frac{P^{(n)}}{|Z_o(\omega)|} \cdot \frac{R_o(\omega)}{|Z_o(\omega)|}$$

$$= \frac{1}{2\rho_o} \left(V^{(n)}\right)^2 R_o(\omega) \qquad (1)$$

where

$$\left.\begin{array}{ll}
\text{acoustic pressure, } p^{(n)} = \mathrm{Re}\left[P^{(n)} \exp(n\omega_o t - \phi_p{}^{(n)})\right] & \\
\qquad = P^{(n)} \cos(n\omega_o t - \phi_p{}^{(n)}) & \\
\text{mass velocity, } v^{(n)} = V^{(n)} \cos(n\omega_o t - \phi_v{}^{(n)}) & \\
\text{phase difference, } \phi^{(n)} = \phi_p{}^{(n)} - \phi_v{}^{(n)} & \\
\text{radiation impedance, } & \\
\qquad Z_o(\omega) \equiv p(\omega)/v(\omega) = |Z_o(\omega)| \, e^{i\phi^{(n)}} & \\
\qquad \equiv R_o(\omega) + i\, x_o(\omega) & \\
\qquad \omega = n\omega_o & \\
\qquad \omega_o = \text{firing frequency in radians/sec.} &
\end{array}\right\} \qquad (2)$$

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To simplify, drop the superscript (n) from all quantities,

$$W = \frac{1}{\rho_O} (\widetilde{pv}) = \frac{1}{2\rho_O} \left(\frac{P}{|Z_O|} \right)^2 R_O = \frac{1}{2\rho_O} V^2 R_O \qquad (3)$$

In this article, unless otherwise stated, p, v, I, and W represent harmonic components of pressure, velocity, intensity, and sound power, respectively.

In mean flow, the radiation of sound corresponding to each component generally increases [5]. The state variables, as well as acoustic pressure and mass velocity, are replaced by perturbations on 'total' pressure and 'total' mass velocity. These variables, called convective pressure and convective mass velocity, are related to acoustic variables as shown below [6].

$$pc = p + M_1 Y_1 v \qquad (4)$$

$$vc = v + M_1 p/Y_1 \qquad (5)$$

M_1 and Y_1 are, respectively, the mean flow Mach number in and characteristic impedance of the tail pipe.

$$M = U/c \qquad (7)$$

$$Y = c/S \qquad (8)$$

U, c, and S are, respectively, mean flow velocity, velocity of wave propagation in a stationary medium, and the cross sectional area of the tube. The sound radiated in the presence of mean flow is given by equation (9).

$$Wc = \frac{1}{\rho_O} (pc)\,(vc) \qquad (9)$$

The equation has been verified experimentally [5]. From equations (2), (3), (4), and (5), it can be seen that

$$\frac{Wc}{W} = 1 + M_1^2 + \frac{M_1}{Y_1} \frac{R_O^2(M_1) + X_O^2(M_1)}{R_O(M_1)} + \frac{M_1 Y_1}{R_O(M_1)} \qquad (10)$$

For sufficiently low frequencies,

$$R_O(M_1) \simeq R_O - (1.1\, M_1)\, Y_1$$
$$X_O(M_1) \simeq X_O\,(1 - M_1^2) \qquad (11)$$

$$R_O \simeq \frac{k^2 a^2}{4} Y_1, \quad ka \leqslant 0.2$$
$$X_O \simeq (0.60\, ka) Y_1, \quad ka \leqslant 0.2 \qquad (12)$$

More exact values of $R_O(M)$ and $X_O(M)$ can be found in Figure 4 of Mechel, Schilz, and Dietz [7].

Equation (9) can be rewritten in the form

$$Wc = \frac{1}{\rho_O} (pc)(vc) = \frac{1}{2\rho_O} \frac{Pc^2}{|Zc_O|^2} Rc_O = \frac{Vc^2}{2\rho_O} \cdot Rc_O \qquad (13)$$

where

$$\left.\begin{aligned} pc &= \mathrm{Re}\left[Pc\, e^{i\omega(t - \phi_{pc})} \right] \\ vc &= \mathrm{Re}\left[Vc\, e^{i\omega(t - \phi_{vc})} \right] \\ \phi c &= \phi_{pc} - \phi_{vc} = \tan^{-1} \frac{Xc_O}{Rc_O} \\ Zc_O &\equiv Rc_O + i\, Xc_O \equiv \frac{pc}{vc} = \frac{p + M_1 Y_1 v}{v + M_1 p/Y_1} = \frac{Z_O(M) + M_1 Y_1}{1 + \frac{M_1 Z_O(M)}{Y_1}} \\ Z_O(M) &= R_O(M) + i\, X_O(M) \end{aligned}\right\} \qquad (14)$$

ANALYSIS OF AN EXHAUST MUFFLER

The primary purpose of a muffler is to reduce the fluctuations in exhaust flow before the gases interact with the atmosphere to radiate sound. A good muffler reduces the amplitudes of all the harmonics without adding unduly to the back pressure of the engine.

Attenuation (ATT) or insertion loss (IL) of an acoustic filter is defined as the ratio of sound radiated without to that radiated with a muffler.

$$ATT = 10 \log_{10} \frac{W_1}{W_2} \qquad (15)$$

W_1 and W_2 require acoustic evaluation of the muffler and/or the exhaust system. Either of two approaches can be used: acoustic wave analysis or finite pulse analysis. In acoustic wave analysis, it is assumed that all amplitudes of harmonic components of particle velocity are much smaller than the velocity of wave propagation. This analysis is easier to work with than finite pulse analysis and has been instrumental in recent advances in design methodology. Both approaches are discussed below.

Acoustic Wave Analysis

Stewart [8] used basic electro-acoustic analogies in deriving the basic theory and design of acoustic filters in 1922. Experimental verification of classical acoustics as applied to various muffler elements and simple combinations was provided in 1954 [9].

A general expression for the attenuation of a muffler was published in 1973; it accounts for finite radiation Z_O and source impedance Z_{n+1}; n is the number of elements constituting the muffler (see Fig. 1(a)). This expression was later written in terms of velocity ratio [10].

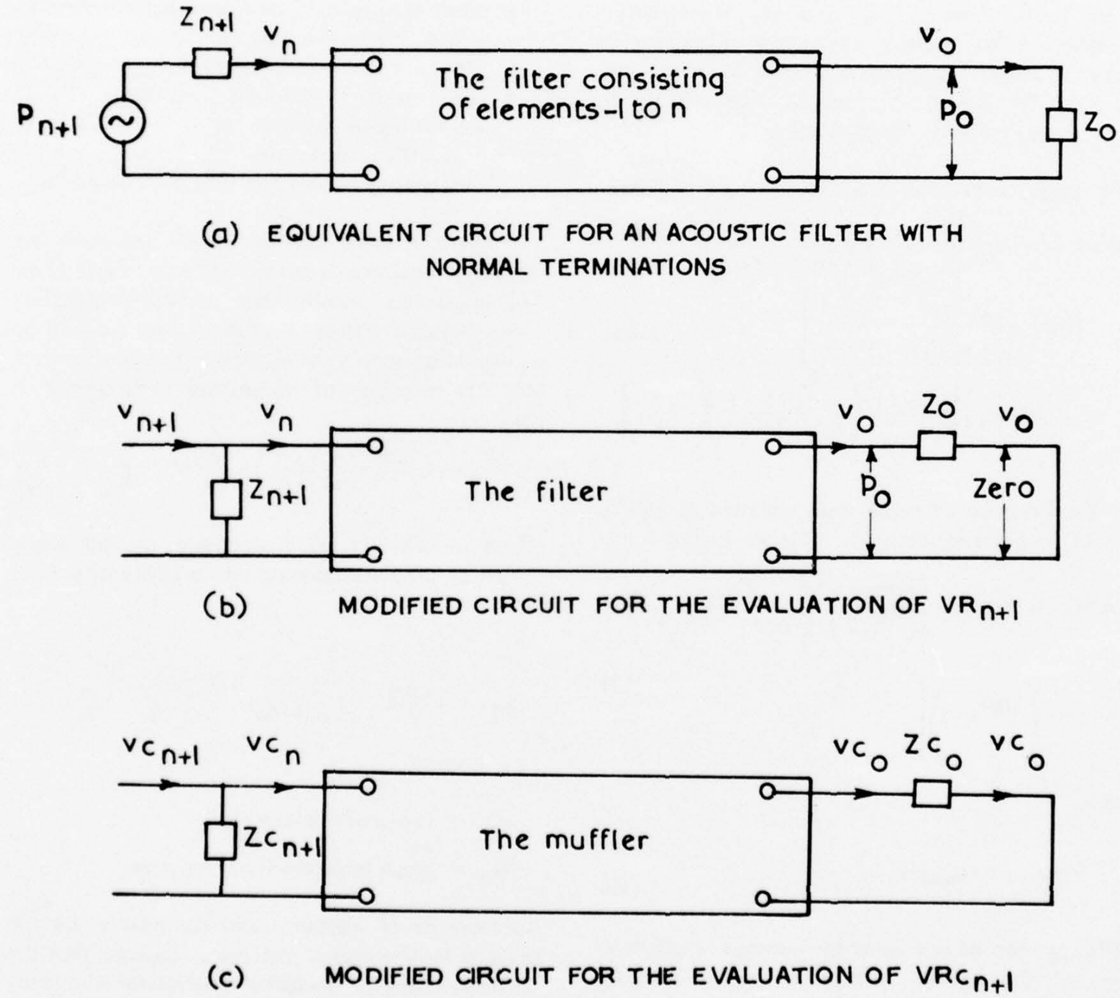


Figure 1. Block Diagrams for the Evaluation of Velocity Ratios

$$\mathrm{ATT} = 10 \log_{10} \left| \frac{Z_{o,1}}{Z_{o,2}} \left(\frac{Z_{n+1}}{Z_{n+1} + Z_{o,1}} \right)^2 \left(VR_{n+1}^2 \right) \right| \tag{16a}$$

Z_{n+1} is the hypothetical internal impedance of the exhaust system; VR_{n+1} is the velocity ratio V_{n+1}/V_o, defined with respect to Figure 1 (b). Subscripts 1 and 2 of Z refer to W_1 and W_2 respectively. Equation (16a) neglects the phase difference ϕ between acoustic pressure and mass velocity; the ratio of the acoustic pressure to mass velocity is the complex radiation impedance Z_o.

The correct expression is shown in equation (16b).

$$\mathrm{ATT} = 10 \log_{10} \left[\left| \left(\frac{Z_{o,1}}{Z_{o,2}} \right) \left(\frac{Z_{n+1}}{Z_{n+1} + Z_{o,1}} \right)^2 \left(VR_{n+1}^2 \right) \right| \frac{R_{o,1}}{|Z_{o,1}|} \; \frac{|Z_{o,2}|}{R_{o,2}} \right] \tag{16b}$$

$$= 20 \log_{10} \left| \left(\frac{R_{o,1}}{R_{o,2}} \right)^{1/2} \left(\frac{Z_{n+1}}{Z_{n+1} + Z_{o,1}} \right) \left(VR_{n+1} \right) \right|$$

In the presence of mean flow, attenuation (ATT) would be given by equation (17); see Figure 1 (c).

$$\mathrm{ATTc} = 20 \log_{10} \left| \left(\frac{Rc_{o,1}}{Rc_{o,2}} \right)^{1/2} \left(\frac{Zc_{n+1}}{Zc_{n+1} + Zc_{o,1}} \right) \left(VRc_{n+1} \right) \right| \tag{17}$$

where

$$VRc_{n+1} = v c_{n+1}/v_o \tag{18}$$

VRc_{n+1} can be calculated by successive multiplication of the transfer matrices of various acoustic elements

$$\begin{bmatrix} pc_{n+1} \\ vc_{n+1} \end{bmatrix} = \begin{bmatrix} Tc_{n+1} \end{bmatrix} \begin{bmatrix} Tc_n \end{bmatrix} \cdots \cdots \begin{bmatrix} Tc_2 \end{bmatrix} \begin{bmatrix} Tc_1 \end{bmatrix} \begin{bmatrix} Tc_o \end{bmatrix} \begin{bmatrix} o \\ vc_o \end{bmatrix} \tag{19}$$

including discontinuities of the muffler [6].

Muffler performance can also be evaluated by a scheme of calculations developed by Alfredson and Davies [11]. The velocity ratio-cum-transfer matrix method, however, is easier to use. The following conclusions were drawn from a heuristic study of the effect of mean flow and source impedance [12]:

- although mean flow would increase the radiation of sound considerably, it would not significantly affect the attenuation of tubular mufflers
- mean flow would make hole-cavity resonators almost ineffective (see Fig. 2, for example). This has been observed experimentally [13, 14]
- larger exhaust manifolds (i.e., lower Z_{n+1}) would lessen exhaust noise, particularly at higher frequencies (see Fig. 3, for example). This has been confirmed [15] with experiments

The effect of mean flow on branch resonators was originally observed experimentally in 1956 [13]. The effect has recently been studied theoretically [14]; acoustic energy dissipation was assumed to be caused by shear flow at the aperture of the resonator. The impedance of the resonator at its aperture is given by

$$Z = i\omega \frac{1 + \frac{16a}{3\pi}}{S_A} + \left(\frac{1}{i\omega} \right) \left(\frac{c^2}{Q} \right) + \frac{4}{3\pi} M(\zeta) \frac{c}{S_A} \tag{20}$$

where a and 1 are, respectively, the radius and length of the neck opening into a cavity of volume Q.

$S_A = \pi a^2$

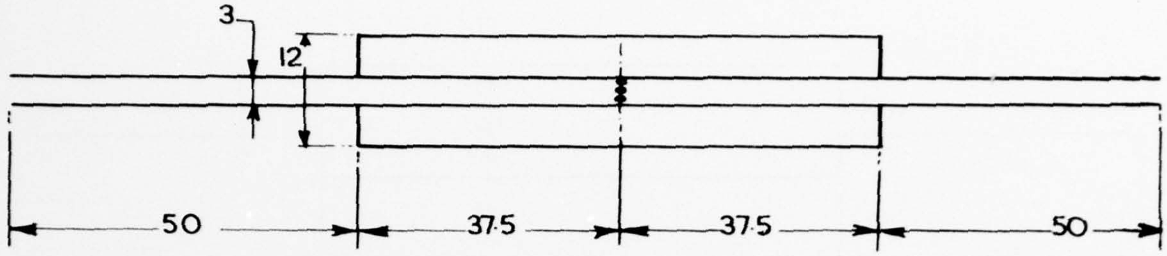
$M(\zeta) = \frac{U(\zeta)}{c} = U_o (\zeta/y_o)^{1/7}$

$\zeta = a/3$

y_o = radius of the flow pipe

U_o = mean flow velocity in the pipe

Components of inertance and compliance are the same as for the case of stationary medium. That the normally negligible resistance term is large with mean flow has been corroborated fairly well by experiments. They show that the attenuation of a branch resonator is considerably reduced by air flow. This is remarkable in the vicinity of a resonance point. As the flow increases and/or the length of the neck decreases, the attenuation peak is reduced.



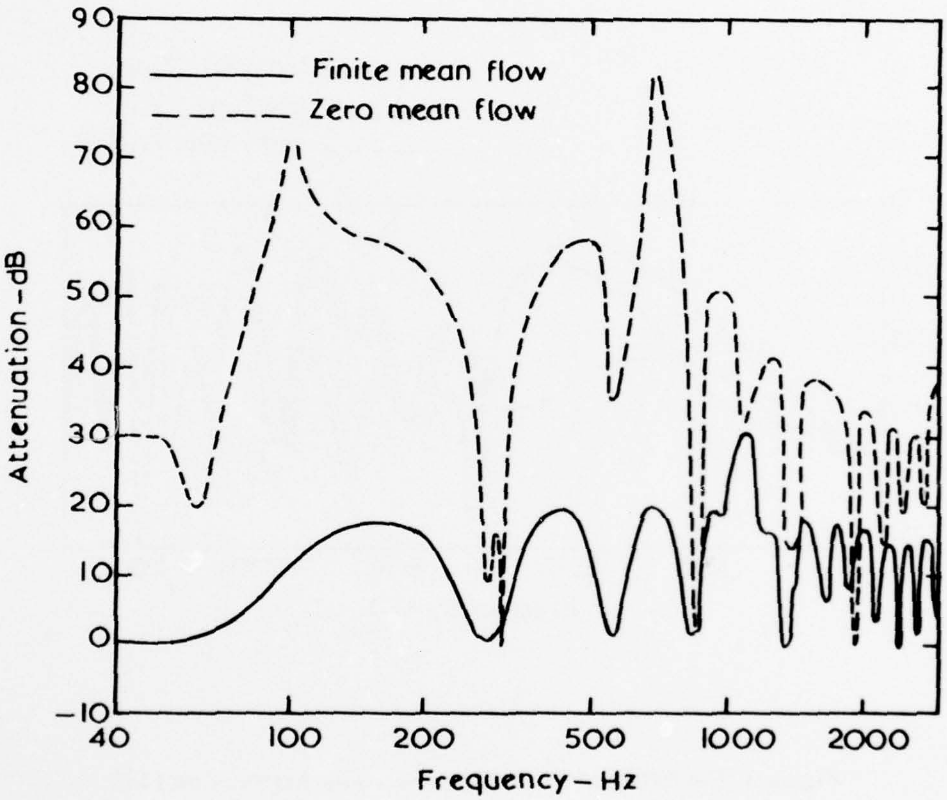
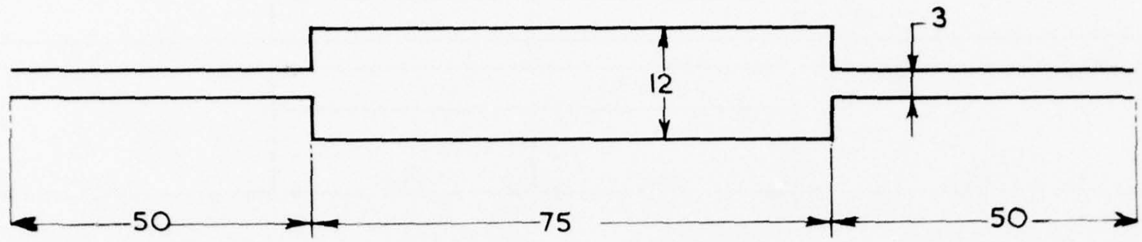


Figure 2. The Effect of Mean Flow on a Hole-Cavity Resonator Muffler [12]



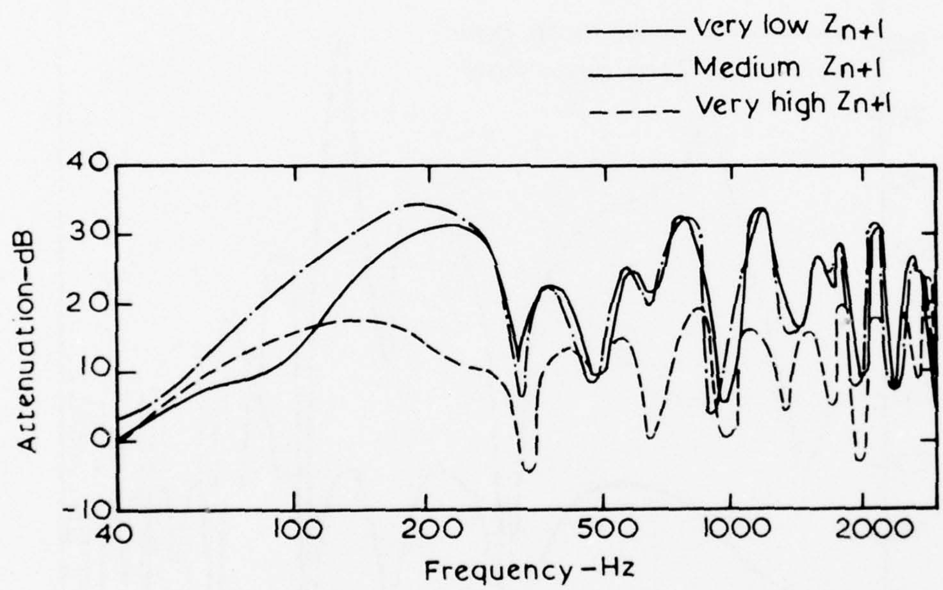


Figure 3. The Effect of Source Impedance on Attenuation [12]

In the presence of mean flow, the wave number of the forward wave becomes $\omega/c(1+M)$; that of the reflected wave becomes $\omega/c(1+M)$. It would seem that the velocity of wave propagation c is multiplied by $1+M$ in one case and $1-M$ in the other. But this effect is limited to wave number; it does not extend to characteristic impedance, which remains unaffected by mean flow [4, 6]. The theoretical analysis [14] is in error inasmuch as the effect is extended to c in the characteristic impedance; however, this is of no consequence because the mean flow Mach number was low ($M^2 \ll 1$) in the experiments.

Ingard and Singhal [16, 17] studied the attenuation of sound in turbulent duct flow with both steady-state and pulsed sound fields. A quasi-static analysis meant to serve as a theoretical basis for the observations agrees fairly well with experimental results. The wave numbers for the downstream (positive) and upstream (negative) directions are shown in equations (21) and (22).

$$k_+ = \frac{\omega}{c(1+M)} - i\,\frac{A}{1+M} \qquad (21)$$

$$k_- = \frac{\omega}{c(1-M)} - i\,\frac{A}{1-M} \qquad (22)$$

The dissipation parameter A is given by

$$A = \alpha + \frac{f M}{2d}\left(1 + \frac{R}{2}\,\frac{\partial(\ln f)}{\partial R}\right) \qquad (23)$$

In equation (23), f is the turbulent flow friction factor, defined by

Δp, $\frac{\rho_0 V^2}{2}\, f\, \frac{L}{d}$, static pressure drop in length L

M, Mean flow Mach number in the duct

d, the ratio between the cross-sectional area of the duct and its perimeter

R, Reynold's number

α, attenuation constant in the absence of flow

A rigorous analysis of the classical problem of axisymmetric transmission of low amplitude waves through a circular pipe containing a viscous fluid has shown that [18]

$$\alpha = \frac{\omega}{ca}\sqrt{\frac{\mu}{2\rho_0\omega}} \qquad (24)$$

The engine's exhaust system, consisting of cylinders (with reciprocating pistons), exhaust valves or ports, and manifold, has eluded acoustic analysis. The sound generated by the system, with and without a muffler, requires characterization of the system as an acoustic source with a hypothetical pressure p_{n+1} and an internal impedance Z_{n+1}. Using effective or convective terminology, the values are pc_{n+1} and Zc_{n+1}. Both hypothetical parameters are functions of such properties of the exhaust system as geometry, speed, and load.

Acoustic impedance of a passive termination is measured with an impedance tube, or transmission line. Measured data is extrapolated to the reflecting surface or to the exact location of the pressure maxima [19]. Lippert's concept of enveloping curves was extended in a method that makes use of the positions of pressure minima, which are usually well defined, and the values of the standing-wave ratio at these points. A similar method has recently been suggested for evaluating the acoustic characteristics of an engine exhaust system and the radiation impedance of the atmosphere [20].

An alternative method has also been suggested. Sound pressure levels L_1, L_2, and L_3, were measured for three mufflers configurations; the same fuel-setting, speed, distance, and angle from the tail pipe termination were used for each configuration. Hypothetical characteristics pc_{n+1} and (real and imaginary parts of) Zc_{n+1} (or p_{n+1} and Z_{n+1}) can be calculated [21]. It is hoped that these attempts will eventually yield semi-empirical expressions for the acoustic characteristics of any exhaust system in terms of its geometry and engine operating parameters.

Finite Pulse Analysis

Finite pulse analysis for the evaluation of exhaust noise was first proposed in 1964 [22]; flow fluctuations in a typical exhaust system were not regarded as small enough to be handled with linear acoustical methods. *Rudinger's wave diagrams* [23] were used to trace a single pulse through simple area discontinuities. A recent method for evaluating sound generated by a rotary valve pulse simulator fed with compressed air has been suggested [24]. A *one-dimensional gas-dynamic* analysis of the unsteady flow within the flow system is performed to obtain a time history of the flow variables [25]. If conditions existing at the end of the pipe are known, the sound radiated is calculated by an expression that seems to be equivalent to equation (25).

$$Wc = \frac{1}{2\rho_O} R_O Vc_O^2 \tag{25}$$

According to equation (13), however, the correct expression would be

$$Wc = \frac{1}{2\rho_O} Rc_O Vc_O^2 \tag{26}$$

Rc_O can be found from equation (14).

$$Rc_O = \frac{\left[R_O(M_1)+M_1 Y_1\right]\left[1+\frac{M_1}{Y_1} R_O(M_1)\right] + \frac{M_1}{Y_1} X_O^2(M_1)}{\left[1 + \frac{M_1}{Y_1} R_O(M_1)\right]^2 + \left[\frac{M_1}{Y_1} X_O \ (M)\right]^2} \tag{27}$$

Thus, the correction to equation (25) is

$$W = 10 \log_{10} \frac{Rc_O}{R_O} \tag{28}$$

With this correction, the method can be extended to the exhaust system of internal-combustion engines; the numerical solution of flow through an engine cylinder with a finite length of straight exhaust pipe can be used [26, 27]. Major difficulties arise when discontinuities occur. An analysis of propagation of finite pulses across areas of sudden expansions has been attempted [28]. The lack of direct experimental corroboration does not inspire confidence in the analytical models, however. Even measurements of the system containing these elements correlate poorly with analytical predictions. The complexity of the computations is also a disadvantage of the method.

One point said to favor this approach is that it does not assume that flow variations are very small (i.e., u need not be much smaller than c). It has been established, however, that finite wave effects are indeed negligible in the evaluation of a muffler [5, 11].

Analytical Modeling of Real Muffler Configurations

Analysis is available [6, 11] for such simple muffler phenomena as sudden expansion and contraction, and extended inlet and outlet. Commercial muffler configurations include bends, elliptical tubes, and flow reversal elements, none of which has been systematically studied.

It has been established [29] theoretically and experimentally that, for tubes with rigid walls and zero mean flow, a bend can be regarded as equivalent to a straight duct; the medium length of the curved section is corrected in proportion to k_c/k_O, the normalized circumferential wave number on the duct centerline, which is plotted in Figure 4.

$$b = \frac{\pi}{4} d$$

R_1 and R_2 are the radii of curvature of the curved section. With the correction to the length of the curved portion of the bend, it is thought that mean flow can perhaps be taken into account in the same way as for straight pipes [6].

The propagation of sound in elliptic ducts without mean flow has been studied analytically [30]. It was concluded that even large deformations of duct shape have little effect on the cutoff frequency, providing the cross-sectional area remains constant along the length; i.e., reference of all calculations is to ellipses of equal area.

A method for analyzing any system component with arbitrary geometry has been developed [31]; the form must be an assembly of rectangular elements. Transmission loss is calculated by forming an equivalent acoustic four-terminal transmission network. The acoustic four-pole constants are calculated by the finite element method. It is claimed that "the method has been applied to complicated shaped

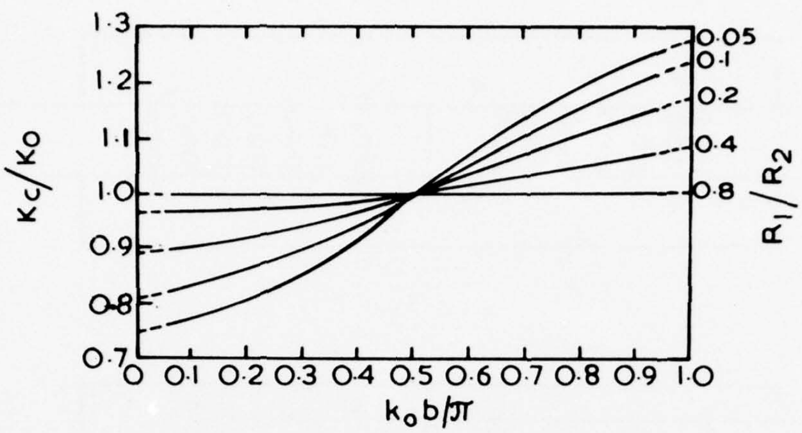


Figure 4. Design Chart for Bends [29]

chambers in mufflers for which plane-wave solutions are not available, and good agreement has been found between the predictions and experiments [31]. The method, however, is not valid for moving media; and in its present form, therefore, the method cannot be applied to exhaust mufflers.

The author has not yet seen any article on the evaluation of mufflers of the type shown in Figure 5. These configurations are known to be very efficient and are widely used in the automotive industry.

DESIGN OF AN EXHAUST MUFFLER

Stewart [8] designed expansion chamber mufflers, likening a small diameter tube to a lumped inertance and a large diameter tube (expansion chamber) to a lumped compliance in the low frequency limit. This analogy was very helpful because about half of the unmuffled noise lies at the firing frequency of the engine, where the product k.1 for any pipe is small enough so that the lumped element approximation holds. Following a systematic study, certain design formulas and curves were deduced from plane wave theory [9]. Alfredson [32] accounted for mean flow in, developing an elaborate computer program for the design of a tubular muffler; this design has been successfully used [33]. The first major step toward a rational synthesis of acoustic filters -- that is, linear dynamic filters, including vibration isolators -- occurred in 1973 with the development of an algebraic algorithm [34] for writing the required velocity ratio [10] in terms of impedances and phase constants of the elements constituting a filter; simultaneous solution of a large number of algebraic equations or successive multiplication of n+2 transfer matrices is not required. The role of a specific element in the entire filter can thus be seen [35]. This algorithm has been used to derive some general criteria for the synthesis of an acoustical filter [36]. Karnopp rederived the synthesis criterion for tubular mufflers [37]. Convective transfer matrices [6] have been used to modify these criteria for a rational synthesis of an exhaust muffler with mean flow [12].

The design of a commercial muffler is thus at best semi-empirical even today. The design of an efficient exhaust muffler for a motor cycle [38] confirms this remark. In order to help truck engine manufacturers and users to select the right silencer (so as to meet legislative requirements, the U.S. Department of Transportation has financed a systematic comparative study of available silencers. The reports [39, 40] show that, measured according to SAE recommended practice J366a [41], muffled exhaust noise of trucks in the U.S. varies from 72.5 to 80 dBA versus unmuffled noise of 82 to 105 dBA, and that turbocharged engines are generally quieter than their counterparts.

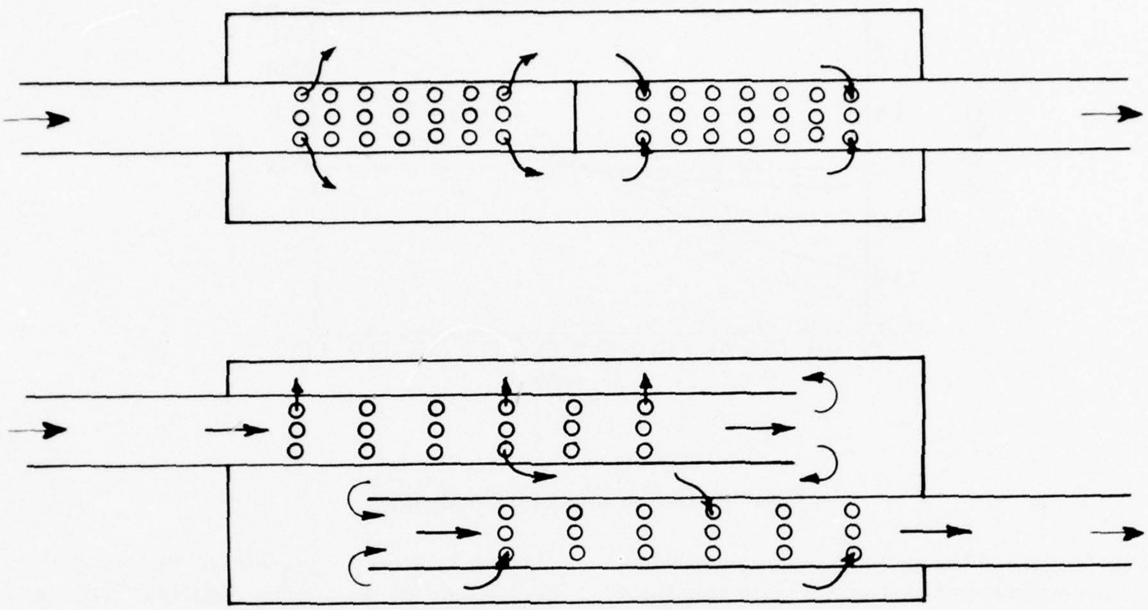


Figure 5. Typical Commercial Muffler Configurations

CONCLUSION

Over the last three or four years, there have been significant advances in the analysis and design of exhaust mufflers. Transmission loss of an exhaust muffler with mean flow can be calculated exactly. Acoustical characteristics of an engine exhaust system can be evaluated experimentally. The configuration of a straight-through muffler can be decided rationally. A tubular muffler can be designed exactly by means of a digital computer program. A start has been made toward a theoretical prediction, with exhaust pulse analysis, of noise that would be generated by an engine exhaust system.

Some of the problems awaiting attention are

- analytical modeling of elements involving reversal of flow or transfer of flow through holes
- prediction of the acoustic characteristics of an exhaust system consisting of cylinders, exhaust valves, exhaust manifold and exhaust pipe
- modeling the propagation of finite exhaust pulses with the discontinuities characteristic of a commercial muffler.

The solution of these problems is a prerequisite to the possible development of a rational procedure for the design of efficient exhaust mufflers.

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BOOK REVIEWS

VOLUME I, STABILITY OF MOTION, VIBRATIONS AND AERODYNAMICS; VOLUME II, STABILITY AND VIBRATIONS OF NONLINEAR SYSTEMS

(Tom I, Ustoichivost dvizhaniya kolebaniya aerodinamika;
Tom II, Ustoichivost i kolebaniya nelineinykh sistem)

G. V. Kamenkov

Moscow, Izadelstvo "Nauka" (1971); (1972)

The two volumes contain "selected papers" of G. V. Kamenkov (1907 - 1966) and a 10-page summary of the scientific work of this Soviet scientist. The first papers are devoted to problems of aerodynamics such as, for instance, theory of fluid resistance and theory of airfoils.

Later the author was active nearly exclusively in the field of vibrations and theory of stability. He has written a monograph ["On the stability of motion," Aeronautical Institute of Kasan, 1939], which is reprinted in these papers. Topics of this theoretical work on the stability of motion are investigations of special cases and critical cases: systems with double-zero roots and with purely imaginary roots, behavior of systems in the vicinity of stability border, stability of periodic motions, and stability of systems with periodic coefficients. A remarkable publication, first given in 1953, deals with the stability of motion in a finite interval of time. Further papers deal with motion and stability of autonomous and nonautonomous nonlinear vibrations.

Many of the topics appear several times in different papers; therefore, the last ones seem to be the most important ones as they contain the abstract of all results found before. Some of the author's methods have become standard methods for the investigation of nonlinear systems.

K. Magnus, Germany
Courtesy of Applied Mechanics Reviews

NOISE AND NOISE CONTROL
VOLUME I
M.J. Crocker and A.J. Price
CRC Press, Inc., Cleveland, Ohio 1975

This is another in the spate of handbooks on noise control that has appeared in the last several years. As a practical book, however, this is one of the better ones, for it is compact, clearly written, copiously referenced, well indexed, and written by authors with backgrounds encompassing research, consulting, and pedagogy.

There are five major chapters:

I. Some Fundamentals of Sound and Vibration
II. Human Hearing and Subjective Response to Sound
III. Instrumentation for Sound and Vibration Measurement
IV. Acoustics of Enclosures
V. Architectural Acoustics

The treatment is modern, and at a level that requires knowledge of some mathematics, although the book is not at the level of difficulty of Beranek's volume. One flaw that disturbed this reviewer is the treatment of response to vibration. Work of Miwa and Diekmann on subjective response is not mentioned; the Reiher-Meister criteria of 1931 are given instead. Only one report on building damage is referenced, and no mention is made, for example, of extensive tests of the U.S. Bureau of Mines or of work in England and Canada.

On the whole, however, given that "Noise control is not easy and there are no magic answers....," this book provides substantial useful information for the practitioner.

Clive L. Dym
Senior Scientist
Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, MA 02138

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

CALL FOR PAPERS
Fifth World Congress on the Theory of Machines and Mechanisms

The Fifth World Congress of the International Federation for Theory of Machines and Mechanisms (IFToMM) will be held in Montreal, Canada, on July 8 - 13, 1979.

The topics covered will include kinematic analysis and synthesis; dynamics of machines and mechanisms; gearing and transmissions; preventive maintenance and reliability control; rotor-dynamics; vibrations and noise in machines; biomechanisms; technology transfer; robots, manipulators and man-machine systems; computer-aided design and optimization; pneumatics, hydraulics and electrodynamics; industrial applications for special machines and mechanisms; experimental and teaching methods.

Papers are invited on subjects of the above fields and related areas. For further information, contact:

Dr. M.O.M. Osman, Conference Chairman
Fifth World Congress on Theory of Machines and Mechanisms
Dept. of Mech. Engrg., Concordia University
1455 de Maisonneuve Blvd. West
Montreal, Quebec, Canada H3G 1M8

INTER-NOISE 78 TO BE HELD IN SAN FRANCISCO

San Francisco is the site of INTER-NOISE 78, the Seventh International Conference on Noise Control Engineering, to be held on May 8 - 10, 1978.

"Designing for Noise Control" is the theme for the conference. Emphasis will be on finding practical solutions to the most important problems of noise control. There will be sessions devoted to industrial noise, transportation noise and environmental noise. In addition to the INTER-NOISE Exhibition at which the latest noise control products will be displayed, papers will be given on noise measurement, analysis and instrumentation. A series of Distinguished Lectures on various aspects of "Designing for Noise Control" will be given by recognized authorities in the field. During the evening Noise Clinics, participants may discuss problems of particular interest with others involved in similar problems. For more information, contact:

Conference Secretariat - INTER-NOISE 78
P. O. Box 3469, Arlington Branch
Poughkeepsie, NY 12603
(914) 462-6719

CALL FOR PAPERS
Eighth U.S. National Congress of Applied Mechanics

The U.S. National Committee on Theoretical and Applied Mechanics announces a call for papers on all fields of mechanics -- fluid mechanics, solid mechanics, mechanics of porous media and dynamics -- for their Eighth U.S. National Congress of Applied Mechanics to be held June 26 - 30, 1978 at the University of California, Los Angeles. For details, contact:

Professor Julian D. Cole
Mechanics and Structures Department
School of Engineering and Applied Science
University of California
Los Angeles, CA 90024

RELIABILITY-QUALITY CONTROL SEMINAR

The tenth seminar on Reliability-Quality Control, sponsored by the Society of Reliability Engineers (SRE) and American Society for Quality Control (ASQC), will be held on Saturday, October 22, 1977, at the Niagara Hilton, Niagara Falls, New York. For more information, contact:

Mr. Vincent R. Daniels
SRE Chairman - 1977
Bell Aerospace Div. of Textron Inc.
P. O. Box One
Buffalo, New York 14240
(716) 297-1000 - ext. 385

SHORT COURSES

AUGUST

SIGNAL PROCESSING SYSTEMS

Dates: August 29 - September 2, 1977

Place: Washington, D.C.

Objective: This course is designed for systems analysts, engineers, managers, and others who need a better understanding of the developing technology of signal processors. The presentation will cover principles and current techniques, including introductory material concerning digital computer systems, state-of-the-art information on the digital logic devices, and modern design techniques used in signal processing. The principles and techniques will be presented so that participants without extensive experience in mathematics may gain a solid understanding of signal processing systems.

Contact: Continuing Engineering Education, George Washington University, Washington, D.C. 20052

SEPTEMBER

FINITE ELEMENT MODELING WORKSHOP

Dates: September 29 and 30, 1977

Place: O'Hare Hilton Hotel, Chicago, Illinois

Objective: The program for this Vibration Institute-sponsored workshop includes lectures, demonstrations, and problem-solving sessions on the use of finite element-oriented computer codes to solve engineering problems. Emphasis will be on modeling hardware to obtain thermal, stress, and vibration data. Existing computer codes -- NASTRAN, ANSYS, and SAP -- will be used. The purpose of this workshop is to teach general purpose computer codes to solve engineering problems. Each participant will have the opportunity to run a problem on a remote terminal situated in the classroom.

Contact: Vibration Institute, 101 W. 55th St., Clarendon Hills, IL 60514-(312)654-2254/654-2053

OCTOBER

NOISE CONTROL

Dates: October 13 - 15, 1977

Place: Hampton, Virginia

Objective: An intensive short course on noise control will be presented immediately preceeding NOISE-CON 77, the 1977 National Conference on Noise Control Enineering. The presentations will cover fundamentals of acoustics and noise control; design of facilities for noise control; noise measurements and data reduction; and acoustical standards used in noise measurements.

Contact: NOISE-CON 77 Conference Secretariat, P.O. Box 3469, Arlington Branch, Poughkeepsie, NY 12603 - (914) 462-6719

NOVEMBER

MACHINERY VIBRATION

Dates: November 8 - 10, 1977

Place: Cherry Hill, New Jersey

Objective: Lectures and demonstrations on rotor dynamics and torsional vibration have been scheduled for this seminar. General sessions on the opening day are intended to serve as a review of the technology; included are the concepts of critical speeds, resonances, and stability of machines; the finite element method; and rotor dynamic measurements. Double sessions on rotor dynamics and torsional vibrations will be held on the second and third days. The following topics are included in the rotor dynamics sessions: bearing (antifriction and fluid film) dynamics, rotor dynamic calculations, dynamics of foundations, application of large computer programs for structural vibration analysis, modern balancing techniques and applications, and solutions to industrial balancing problems. The sessions on torsional vibration feature fundamentals, modeling measurement and data analysis, self-excited vibrations, isolation and damping, transient analysis, and design of machine systems. Participants will be able to attend lectures in the area commensurate with their interests.

Contact: Vibration Institute, 101 W. 55th St., Clarendon Hills, IL 60514 (312)654-2254/654-2053

AN INTRODUCTION TO VIBRATION AND SHOCK SURVIVABILITY, MEASUREMENT, ANALYSIS, CALIBRATION AND TESTING

Dates: November 7 - 11, 1977

Place: Washington, D.C.

Objective: This course is intended to provide a basic education in resonance and fragility (vulnerability) phenomena, in vibration and shock environmental measurement and analysis, also in vibration and shock testing to prove reliability. This seminar will benefit quality and reliability personnel, test laboratory managers, engineers and aides, plant engineers and maintenance supervisors, packaging and transportation engineers, men in Government and military activities and their contractors. There are no definite prerequisites for this course.

Contact: Tustin Institute of Technology, Inc., 22 E. Los Olivos St., Santa Barbara, CA 93105 (805) 963-1124.

GIFTS USERS WORKSHIP

Dates: October 31 - November 4, 1977

Place: The University of Arizona, Tucson

Objective: To introduce the users to the GIFTS System and provide them with adequate experience with an understanding of the program. The GIFTS program is a collection of program modules designed to handle finite element computations in an automated, graphically-oriented fashion. The programs run in a small core space on many mini-computers and time sharing systems. The program capabilities include automatic model and load generation, result display, static and dynamic analysis including substructuring. It is expected that additional modules will be available for solid analysis and display, as well as axisymmetric solid analysis under arbitrary loading.

Contact: The University of Arizona, Special Professional Education College of Engrg., Tucson, AZ 85721 (602) 884-3054/884-1755

THE 15TH ANNUAL RELIABILITY ENGINEERING AND MANAGEMENT INSTITUTE

Dates: November 14 - 18, 1977

Place: Tucson, Arizona

Objective: This seminar, presented by the University of Arizona, College of Engineering and Honeywell Information Systems, Arizona Computer Operations, Phoenix, is designed to cover the following subjects: Reliability Engineering Theory and Practice; Component, Equipment and System Reliability Prediction; Reliability Testing and Demonstration; Maintainability Engineering Theory and Practice; Safety; Liability; and Reliability and Maintainability Management.

Contact: Dr. Dimitri Kececioglu, Aerospace and Mechanical Engrg. Dept., University of Arizona, Bldg. 16, Tucson, Arizona 85721 (602) 884-2495/884-3901/884-3054.

ACOUSTICAL MODELING WORKSHOP IV

Dates: November 14 - 18, 1977

Place: MIT, Cambridge, Massachusetts

Objective: Participants will build their own models, take and interpret data to solve complex acoustic propagation problems. Sessions will consider applications of data to environmental noise prediction, evaluation of noise control measures, and site selection for buildings, roadways and guidways. Some subjects covered include sound speed, frequency and geometric scaling, air absorption, surface reflectivity, impulsive and continuous signals, spatial distribution of sources, interior and exterior noise situations and their characteristics, effect of barriers and absorbers in control of noise, control of reverberation, and the use of data in design.

Contact: Ms. M. Toscano, Rm. 3-366, Acoustical Modeling Workshop IV, Massachusetts Institute of Technology, Cambridge, MA 02139

REVIEWS OF MEETINGS

INSTITUTE OF ENVIRONMENTAL SCIENCES
23rd Annual Technical Meeting
April 25-27, 1977
Los Angeles, California

The theme of this meeting was "Environmental Technology '77". In keeping with the IES mission the more than sixty sessions covered essentially all technical areas within the environmental sciences. The energy problem was emphasized in a challanging and thought provoking address at the Awards Banquet, "ENERGY CRISIS: Alternate Solutions by 1982", given by the eminent Dr. Edward Teller. The areas of Test and Evaluation and Reliability continue to receive considerable attention as typified by two outstanding keynote addresses.

Lt. General Walter E. Lotz, Jr., USA (Ret.) Kickoff Keynote Speaker for the 23rd Annual Technical Meeting and Equipment Exposition began the symposium with the kind of presentation which reflects the enthusiasm and vigor of the new IES. He prepared the way for the co-speaker and set the theme for the meeting. The message was to the point and laid the DoD's position in R&E and Test and Evaluation out in a very forthright and Romanistic approach. As the top Department of Defense Official in T&E he very effectively and authoritatively outlined the interface between the Government and Industry. His approach was basic and realistic. He combined the analytical, practical, and testing phases of weapon systems development. Acceptance procedures required for certification and final production were discussed. His main thrust to the audience was that a system must not only pass the rigor of testing but must be operationally useable in the field over its projected lifetime with a minimum cost and down time.

Colonel Ben H. Swett, USAF, carried General Lotz's opening theme into greater detail, relating the overall test and evaluation process to performance, reliability, maintainability and environmental considerations. He emphasized the need for and value of the "TEST-FIX-TEST" approach to engineering development. Colonel Swett introduced some of the concepts included in a new DoD directive 5000X which stresses "burn in" and independent testing and evaluation.

Under the general subject of Reliability there were a total of seven sessions illustrating significant progress in areas such as specifications and standards, methodology and test equipment. The success here is due largely to notable IES efforts under the leadership of R.N. Hancock and Stan Baber.

The program on Dynamics contained four sessions with scheduled technical papers, a panel session on computer controlled environmental testing, and a Show and Tell session involving the presentation of short papers that will not be published. The technical papers covered a variety of subjects such as solution of special vibration problems, response of structures to overpressure, prediction of noise and vibration in helicopters, response to acoustic loadings, and vibration and acoustic testing methods and techniques. The papers were well-received and useful. Those appearing in the IES Proceeding will be abstracted in a future issue of this DIGEST.

The panel session on Computer Controlled Environmental Testing was reported to be well attended and extremely useful. The moderator was Phil Chapman of JPL who had previously received the Vigness Award for his work in this area. The Show and Tell session, patterned after similar efforts at Shock and Vibration Symposia, was somewhat short on speakers but was considered to be an initial success. More sessions of this type are to be expected at future IES meetings.

Congratulations are in order for Richard L. Baker, General Chairman, Stanley Baber, Technical Program Chairman, and other members of the 1977 Annual IES Meeting Management Committee for a very successful effort.

H.C.P.

Note: Special thanks to Frederick W. Rusch, Rockwell International for assistance with this review.

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U. S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN

ANALYTICAL METHODS

77-1415

Determination of Eigenvalues of Large Structural Systems in an Arbitrarily Specified Range

M.K. Kaul

EDS Nuclear Inc., San Francisco, CA, Intl. J. Numer. Methods Engr., 11, pp 867-874 (1977) 2 figs, 2 refs

Key Words: Eigenvalue problems

For a large structural system of small bandwidth a technique combining linear interpolation on the characteristic polynomial and suppression of its previously determined roots by deflation can be used to determine its eigenvalues. The eigenvalues, however, have to be found in order, beginning from either the lowest (or the highest) to obtain monotonic convergence to the polynomial roots. A method which eliminates this restriction is presented in this paper. Some consequences of the procedure developed in this paper are also presented and it is shown that the standard deflation technique is a special case of this procedure. The method has been applied to a wide range of problems with success and considerable saving in computation time.

77-1416

A Study on the Forced Vibrations of a Class of Nonlinear Systems, with Application to the Duffing Equation. Part II: Numerical Treatment

R. Riganti

Istituto di Meccanica Razionale, Politecnico di Torino, Meccanica, 11 (2), pp 81-88 (June 1976) 9 figs, 2 tables, 10 refs

Key Words: Forced vibration, Duffings differential equations

Numerical results on the wave form, the amplitude and the phase of the steady state solutions of the Duffing equation are obtained in this paper. The steady state vibrations are studied by a procedure of direct numerical integration based on the Runge-Kutta method; by calculating the approximate solution of the equation which is obtained, as a particular case, from the theory developed in Part I. The results obtained by the two methods are compared and tested by the results of other authors. From the comparisons it appears that the theory of Part I gives satisfactory results also in the cases of strong nonlinearity of the system.

NUMERICAL ANALYSIS

(Also see No. 1471)

77-1417

Analysis and Design of Numerical Integration Methods in Structural Dynamics

H.M. Hilber

Earthquake Engrg. Research Center, Univ. of California, Berkeley, CA, Rept. No. EERC-76-29, 102 pp (Nov 1976)

PB-264 410

Key Words: Earthquake resistant structures, Mathematical models, Numerical analysis

The objective of this work was to develop one-step methods for the integration of the equations of structural dynamics which are (A) unconditionally stable, (B) have an order of accuracy not less than two, and (C) possess numerical dissipation which can be controlled by a parameter other than the time step size. In particular, no numerical dissipation must be included. Four new families of algorithms are discussed from this point of view, and compared with algorithms, such as the Newmark, Wilson and Houbolt methods, which are commonly used in structural dynamics and do not achieve these requirements.

STATISTICAL METHODS

(See No. 1524)

MODELING

(See Nos. 1422, 1423, 1447, 1483)

PARAMETER IDENTIFICATION

77-1418

Identification of Vibrating Systems by Generic Modelling with an Application to Flutter

P.J. Holmes and D.A. Rand

Inst. of Sound and Vibration Research, Southampton Univ., UK, Rept. No. ISVR-TR-79, 143 pp (Nov 1975)

Sponsored by the Sci. Research Council and Social Sci. Research Council

N77-17518

Key Words: System identification, Flutter

The aim of this paper is to indicate how recent mathematical work on qualitative dynamics makes possible an accessible but rigorous synthesis of the intuitive, theoretical, and empirical aspects of certain engineering problems. This leads to a new, and usable approach to the problem of the identification of complex dynamical systems such as those of vibration engineering. An application of the approach to aeroelastic flutter is included together with an outlined synthesis of the intuitive, lumped element, continuum mechanical and experimental aspects of this problem. The onset of flutter and divergence correspond to a bifurcation in the governing dynamical system. In the presence of such bifurcations, and under reasonable hypotheses, center manifold theory can be used to reduce the complexity of the problem.

SURVEYS AND BIBLIOGRAPHIES

77-1419

Rotor-Bearing Dynamics: State-of-the-Art 1976

N.F. Rieger

Dept. of Mech. Engrg., Rochester Institute of Tech., Rochester, NY, Shock Vib. Dig., 9 (5), pp 5-14 (May 1977) 81 refs

Key Words: Reviews, Rotor-bearing systems, Computer programs, Balancing techniques, Stability, Torsional response

This paper reviews recent developments in rotor dynamics and torsional dynamics of drive trains. The following topics are included: computer programs, balancing techniques, stability, and torsional dynamics of rotor systems. Attention is also drawn to a number of important remaining problems.

77-1420

Underwater Fluid-Structure Interaction. Part I: Introduction and Scope

L.H. Chen and M. Pierucci

General Dynamics Electric Boat Div., Groton, CT 06340, Shock Vib. Dig., 9 (5), pp 23-24 (Apr 1977)

Key Words: Reviews, Interaction: fluid-structure

Fluid-structure interaction encompasses a broad spectrum of technical areas of interest in engineering application. This discussion is limited to "underwater" applications and includes the following topics: sound radiation and scattering, structural vibration and shock response, flow-induced noise, hydrodynamic divergence and flutter, boundary layer stability, and propeller-induced forces. The common thread linking these technologies, namely, the interaction phenomenon, is stressed. An attempt has been made to clarify some of the terminology within these diverse technical areas.

77-1421

Underwater Fluid-Structure Interaction. Part II: Mechanically-Applied Forces

L.H. Chen and M. Pierucci

General Dynamics Electric Boat Div., Groton, CT 06340, Shock Vib. Dig., 9 (5), pp 17-23 (May 1977) 58 refs

Key Words: Reviews, Interaction: fluid-structure, Ships, Shells

Digital computers are now commonly used in the dynamic analyses of complex structures in vacuo. Several general-purpose computer programs using the finite-element method are available; e.g., the NASTRAN codes developed by the NASA Langley Research Center. Specialized programs, such as the BOSOR code developed at the Lockheed Research Center (which is applicable for axi-symmetric shells including branched shell capability) have increased the computational efficiency of and expanded the use of computers in practical design and analysis. This capability has now been extended to the study of a structure subjected to one or more periodic forces and immersed in a stationary, inviscid-fluid medium. The problem is represented by equations (4) to (7). (see the April 1977 issue of the Shock and Vibration Digest.)

77-1422

A Review of Ship Hull Vibration. Part I: Mathematical Models

J.J. Jensen and N.F. Madsen

Dept. of Ocean Engrg., The Technical Univ. of Denmark, 2800 Lyngby, Denmark, Shock Vib. Dig., 9 (4), pp 13-22 (Apr 1977) 138 refs

Key Words: Reviews, Ship hulls, Ship vibration, Mathematical models

This paper is a review of the analytical and numerical tools used to calculate hull vibrations. Mathematical Models are described in the first part. The second part on Modeling of Physical Phenomena contains descriptions of mathematical models of the hull. Numerical determination of the equations of motion is discussed in the third part -- Methods of Solution. The fourth part, Comparison of Beam Models, is a review of methods used to solve the equations of motion; an example problem illustrates various principles.

77-1423

A Review of Ship Hull Vibration. Part II: Modeling Physical Phenomena

J.J. Jensen and N.F. Madsen

Dept. of Ocean Engrg., The Technical Univ. of Denmark , 2800 Lyngby, Denmark, Shock Vib. Dig., 9 (5), pp 25-38 (Mar 1977) 3 figs, 137 refs

Key Words: Reviews, Ship hulls, Ship vibration, Mathematical models

Formulations of the equations of motion were described in Part I: Mathematical Models (see the April 1977, issue of the Shock and Vibration Digest). In order to solve these equations a number of physical quantities that describe the ship and the surrounding water must be determined. These quantities include hull stiffness, hull mass and virtual added mass of water, exciting forces, and damping. The accuracy to which these quantities must be known depends on the complexity of the mathematical model and the distributions of the physical quantities. The value of some quantities depends on the frequency and mode of vibration.

77-1424

Damping Capacity of Structural Materials

J.R. Birchak

Lynchburg Research Center, Babcock and Wilcox, Lynchburg, VA 24505, Shock Vib. Dig., 9 (4), pp 3-11 (Apr 1977) 2 figs, 2 tables, 34 refs

Key Words: Reviews, Material damping

Damping devices are frequently added to structures to prevent unwanted vibrations. Alternatively, structural materials with high internal friction sometimes provide sufficient damping. This review article surveys damping mechanisms that produce significant internal friction in structural materials. Damping capacity is presented as a function of vibrational stress amplitude for selected materials. Data from available literature are used to compare the relative dissipation of various mechanisms: viscoelastic relaxation, dislocation motion, two-phase interface slip, and magnetomechanical damping. These mechanisms have been used to reduce objectional vibrations in automotive disc brakes and in turbine blades.

77-1425

The Development and Testing of Vibration-Damping Materials

S.M. Brown

Armstrong Cork Co., Lancaster, PA, S/V, Sound Vib., 11 (4), pp 28-33 (Apr 1977) 12 figs, 8 refs

Key Words: Vibration damping, Damping materials, Testing techniques, Reviews

The state-of-the-art with respect to vibration-damping materials and tests is discussed from the point of view of a manufacturer of vibration-damping treatments. Past and present product types and test methods are considered. General avenues for future product requirements and future tests are indicated.

77-1426

Air-Cushion-Supported Vehicle Fan Dynamic Response: A Review of the Literature

D.D. Moran

Performance Dept., David W. Taylor Naval Ship Res. and Dev. Center, Bethesda, MD., Rept. No. SPD-695-01, 98 pp (June 1976)

AD-A035 907/5GA

Key Words: Fans, Surface effect machines, Dynamic response, Reviews

The mechanisms which constitute the dynamic response of air-cushion-supported vehicle lift fans subjected to unsteady excitation are summarized and examined through a review of research as reported in literature published between 1932 and 1976.

MODAL ANALYSIS AND SYNTHESIS

77-1427

Applications of Modal Analysis Using Transient Excitation

A. MacKay and A.C. Dougan

Noise and Vib. Sec., Special Projects Div., National Engineering Laboratory, Noise Control, Vib. and Insul., 8 (4), pp 120-125 (Apr 1977) 8 figs

Key Words: Modal analysis, Resonant frequency, Mode shapes, Transient excitation

This paper discusses a technique which can be used to determine the resonant frequencies and mode shapes of a wide range of structures and components. Input forces are provided by a hand-held impact device and the advantages of this approach over conventional shaker tests are discussed. Two applications of the technique are described and in one of these the results are compared with results from double pulse holography tests.

77-1428

Substructure Coupling for Dynamic Analysis and Testing

R.R. Craig, Jr. and C. Chang

Texas Univ., Austin, TX, Rept. No. NASA-CR-2781, 91 pp (Feb 1977)

N77-17512

Key Words: Component mode synthesis

Fixed interface and free interface methods of substructure coupling for dynamic analysis are discussed. Three methods for reducing the number of coordinates required by fixed interface methods are introduced. Matrix ordinary differential equations are employed to improve accuracy in free interface substructure coupling methods.

COMPUTER PROGRAMS

GENERAL

(Also see Nos. 1460, 1483, 1502, 1503)

77-1429

DEPROP - A Digital Computer Program for Predicting Dynamic Elastic-Plastic Response of Panels to Blast Loadings

L.J. Mente and W.N. Lee

Kaman Avidyne, Burlington, MA., Rept. No. KA-TR-133, AFATL-TR-76-71, 200 pp (June 1976)

AD-A035 644/4GA

Key Words: Computer programs, Panels, Blast loads

The DEPROP digital computer program determines the dynamic elastic-plastic, large displacement response of cylindrical and flat panels to arbitrary blast loadings. The program computes strain, stress, displacement and boundary reaction force time histories for linear elastic and elastic-plastic solution options. The theoretical formulation and program description of DEPROP are presented in the form of a User's Manual.

77-1430

Note on the Dynamic Buckling of Elasto-Plastic Structures

M.P. Bieniek

Weidlinger Associates, NY, 58 pp (Oct 1976)

AD-A035 964/6GA

Key Words: Dynamic structural analysis, Elasto-plastic properties, Computer programs, Submerged structures

This note reviews several topics related to the analysis of dynamic buckling and post-buckling behavior of elasto-plastic structures. It is aimed at providing a background for a dynamic elastic-plastic structural analysis code that is being developed to study the dynamic buckling and post-buckling behavior of submerged structures under transient pressure loadings.

77-1431

Static and Dynamic Buckling of Shallow Spherical Shells Subjected to Axisymmetric and Nearly Axisymmetric Step-Pressure Loads Using SATANS-IIA, A Modified Version of SATANS-II

M.D. Shutt

Naval Postgraduate School, Monterey, CA., 168 pp (Dec 1976)

AD-A035 911/7GA

Key Words: Spherical shells, Dynamic buckling, Computer programs

A digital computer program for the geometrically nonlinear analysis of totally arbitrarily loaded shells of revolution (SATANS-2) was modified to more accurately account for the conditions at the pole of the shell. This program was used to determine the buckling load of shallow spherical shells of various sizes when subjected to static axisymmetric, dynamic axisymmetric, and dynamic nearly axisymmetric step-pressure loads of infinite duration. A comparison was made between the new buckling results and previous results obtained without the new pole routine. The comparison revealed a significant change in the buckling pressures, due solely to the change in the pole routine. The new static axisymmetric, dynamic axisymmetric, and even the dynamic asymmetric critical buckling pressure loads appear to be fairly reliable results for perfect, shallow shells.

ENVIRONMENTS

ACOUSTIC

(See Nos. 1438, 1440, 1441, 1492, 1493, 1494, 1495, 1497, 1509, 1511, 1512, 1513, 1514, 1515, 1516, 1517, 1518, 1520, 1524, 1531)

RANDOM

(See No. 1496)

SEISMIC

(See No. 1417)

SHOCK

(See Nos. 1429, 1483, 1500, 1501, 1502, 1507, 1522, 1527, 1528, 1530)

PHENOMENOLOGY

DAMPING

(Also see Nos. 1424, 1425, 1450, 1451)

77-1432

On the Damping Decrement for Non-Linear Oscillations

M.L. Rasmussen

Aerospace Mech. and Nuclear Engrg., Univ. of Oklahoma, Norman, OK 73069, Intl. J. Nonlinear Mech., 12 (2), pp 81-90 (1977) 3 figs, 10 refs

Key Words: Damping coefficients

The logarithmic damping decrement is obtained as a function of arbitrary non-linear restoring forces and arbitrary, but small, non-linear damping forces. General expressions are obtained for both amplitude-dependent and speed-dependent damping. The special case of a cubic restoring force with quadratic amplitude-dependent damping and the special case of a cubic restoring force with quadratic speed-dependent damping are considered in detail. The results of the analysis suggest how experimental data can be utilized to identify and evaluate the damping parameters for a given non-linear oscillator.

77-1433

An Automatically Driven Torsion Pendulum for the Continuous Measurement of Amplitude and Amplitude-Independent Damping

H. Bartesch and D.R.G. Williams

Chemical Engrg. Dept., Univ. of Adelaide, Adelaide, South Australia 5001, J. Phys. E. (Sci. Instr.), 10 (4), pp 416-420 (Apr 1977) 5 figs, 2 tables, 9 refs

Key Words: Pendulum, Measuring instrument, Damping coefficients

A driven torsion pendulum is described which is capable of directly and continuously measuring the energy loss of materials as a function of the amplitude and the number of repeated cycles. A high tensile stress can be imposed to enable the energy loss to be determined at various points on the tensile stress-strain characteristic of the material. Because the energy loss is obtained from the electrical energy required to maintain oscillation at a set amplitude, the damping can be obtained for specimens which exhibit amplitude-dependent behavior.

77-1434

"The Wear of Non-Metallic Materials" 3rd Leeds-Lyon Symposium on Tribology

D.F. Wilcock

Mechanical Technology, Inc., Latham, NY 12110, J. Lubric. Tech., Trans. ASME, 99 (2), pp 147-151 (Apr 1977) 4 figs, 36 refs

Key Words: Wear, Polymers, Coulomb friction

The 1976 Symposium is reviewed. This is the third symposium in a series alternating between University of Leeds, UK and INSA (Institute Nationale Scientifique Applique), Lyons, France. Proceedings may be purchased from either institution. In the keynote address Professor D. Tabor of Cambridge University reviewed some experimental evidence on the wear mechanisms of polyethylene and other polymers. Main areas covered by the symposium were: the wear of polymers; wear of biological and implant materials; dry wear; the wear of graphite; fracture and filled materials; and applications.

FLUID

(Also see Nos. 1420, 1421, 1467, 1469)

77-1435

Understanding Flow-Induced Vibrations. Part II: Fluid/Structure Coupling; Design Considerations

M.W. Wambsganss

Argonne National Lab., Argonne, IL., S/V, Sound Vib., 11 (4), pp 18-21 (Apr 1977) 4 figs, 11 refs

Key Words: Fluid-induced excitation, Interaction: structure-fluid

This two-part article was prepared to provide some general insight into fluid forcing and the associated flow-induced vibration. Two classes of fluid forces are identified. In Part I, fluid excitation forces -- forces that exist independent of structural motion -- were categorized and briefly discussed (Nov 1976, S/V, p 18). In this, the second part, fluid/structure coupling -- forcing that requires structural motion -- is discussed and illustrated. Recommendations for designing to minimize the potential for detrimental flow-induced vibration are also presented.

THERMOELASTIC

(See No. 1473)

EXPERIMENTATION

BALANCING

(See No. 1529)

DIAGNOSTICS

77-1436

Feasibility of Flaw Detection in Railroad Wheels Using Acoustic Signatures

K. Nagy and R.D. Finch

Transportation Systems Center, Cambridge, MA, Rept. No. DOT-TSC-FRA-76-6, FRA/ORD-76/290, 206 pp (Oct 1976)

PB-263 248/7GA

Key Words: Diagnostic techniques, Acoustic signatures, Wheels, Railroad cars

The feasibility study on the use of acoustic signatures for detection of flaws in railway wheels was conducted with the ultimate objective of development of an intrack device for moving cars. Determinations of the natural modes of vibrating wheels under various conditions are reported. Differences in acoustic signatures are found between good and cracked wheels, including spectral changes and variations in the time decay of sound. Various sounds occurring in normal railroad practice, such as rolling noise on welded rail and over joints and retarder screech were investigated. Pattern recognition techniques were used for selecting good and bad wheels with a computerized processing scheme. A laboratory demonstration system has been constructed and found to be 85% reliable when system malfunctions are discounted.

77-1437

Measuring Vibration on Turbine Blades by Optical Means

H. Roth

Brown Boveri Rev., 64, pp 64-67 (Jan 1977) 2 figs, 3 refs

Key Words: Diagnostic techniques, Optical measuring instruments, Turbine blades

The principle of an optical measuring instrument developed in the author's laboratory for thermal machines is explained and tests reported on. This system is adaptable, making it universally suitable for investigating all types of vibration in rotating blades.

INSTRUMENTATION

(Also see Nos. 1441, 1505)

77-1438

Considerations Relating to Instruments for the Measurement of Equivalent Continuous Noise Levels (LEQ)

R.F. Norgan

Computer Engrg. Ltd., Noise Control, Vib. and Insul., 8 (4), pp 127-130 (Apr 1977) 4 figs

Key Words: Measuring instruments, Noise measurement, Noise meters

The first acoustic instrument that CEL ever produced was a Noise Average Meter, or Leq meter, back in 1972 and since then they have refined the techniques involved and produced a number of instruments that measure Leq or its related parameter Noise Dose. Design problems encountered in Leq meters and basic principles of Leq are described.

77-1439

Measurement of the Force-Time-Behaviour and the Peak Periods of Mechanical Impacts (Messung des Kraft-Zeit-Verhaltens und der Stosszeiten bei mechanischen Stössen)

M. Rauch and W. Schmidt

Tech. Hochschule Karl Marx Stadt, East Germany, Maschinenbautechnik, 26 (2), pp 75-77 (Feb 1977) 11 figs, 3 refs

(In German)

Key Words: Measuring instruments, Impact response

A device for the dynamic measurement of force caused by an impact is described. The data receiver is based on a force-dependent resistance. The force-time process and the measurement of individual peak periods during chatter and the time between impacts is presented. Several impact-force oscillograms and measured peak periods indicate application possibilities of the described procedure.

TECHNIQUES

(Also see Nos. 1425, 1427, 1530)

77-1440

Can Correlation Techniques be Used for the Measurement of Vehicle Noise?

J.D. Chalupnik and C.R. Harper

Dept. of Mech. Engrg., Univ. of Washington, Seattle, WA 98195, Noise Control Engr., 8 (1), pp 16-23 (Jan/Feb 1977) 13 figs, 12 refs

Key Words: Correlation techniques, Measurement techniques, Noise measurement, Ground vehicles

The applicability of correlation techniques to the practical problem of measuring the noise level of a single vehicle on a busy road is investigated. Methodological theory is developed for the case of a two-microphone array, and an analysis of the system error is presented. Data from controlled experiments with random noise sources in the field indicate that the method works well on noise sources with signatures relatively free of periodic content; if high-speed, hard-wired instruments are used, the technique should be capable of coping with vehicle motion.

77-1441

Propeller Aircraft Flyover Noise Testing

J.C. Shreve

Wallace Div., Cessna Aircraft Co., SAE Paper No. 770443, 8 pp, 2 figs, 5 tables

Key Words: Noise, measurement, Measurement techniques, Measuring instruments, Aircraft noise

Flyover noise testing of propeller aircraft requires specific instrumentation and test procedures to comply with U.S. and Foreign regulations. This paper presents representative techniques and equipment used in conducting these tests.

77-1442

Characteristics of an Anechoic Chamber for Fan Noise Testing

J.A. Wuzyniak, L.M. Shaw, and J.D. Essary

Lewis Research Center, NASA, Cleveland, OH, Rept. No. NASA-TM-X-73555, E-8993, 32 pp (1977) Sponsored by the American Society of Mech. Engrs. N77-18168

Key Words: Testing facilities, Anechoic chambers, Fans, Noise measurement

Acoustical and mechanical design features of NASA Lewis Research Center's engine fan noise facility are described. Acoustic evaluation of the chamber, which is lined with an array of stepped wedges, is described. Results from the evaluation in terms of cut-off frequency and non-anechoic areas near the walls are detailed. Fan models are electrically driven to 20,600 rpm in either the inlet mode or exhaust mode to facilitate study of both fore and aft fan noise. Inlet noise characteristics of the first fan tested are discussed and compared to full-scale levels. Turbulence properties of the inlet flow and acoustic results are compared with and without a turbulence reducing screen over the fan inlet.

77-1443

Frequency Analog Measurement Technique: Linear Displacement Transducing by Means of a Vibrating String

D. Bouts and Th. Gast

Institut f. Mess- und Regelungstechnik, Fachbereich 10 (Verfahrenstechnik), Technische Universität, Kurfürstendamm 195/196, 1000 Berlin 15, Germany. Techn. Messen, 44 (4), pp 125-130 (Apr 1977) 8 figs, 10 refs

(In German)

Key Words: Measurement techniques, Vibration measurement, Strings

As frequency analog signals are gaining increasing importance for the measurement of mechanical parameters in process control, the design of a displacement transducer based on a vibrating string will be explained. The measurement ensues by cross shifting one clamping place of a vibrating string. The characteristic curve is a hyperbola which approaches its asymptote more and more if the tension of the wire in the resting position is reduced to zero.

COMPONENTS

BEAMS, STRINGS, RODS, BARS

77-1444

On the Dynamic Behaviour of Structural Elements Carrying Elastically Mounted, Concentrated Masses

P.A.A. Laura, E.A. Susemihl, J.L. Pombo, L.E. Luisoni, and R. Gelos

Inst. of Applied Mechanics, Base Naval Puerto Belgrano, Argentina, Applied Acoustics, 10 (2), pp 121-145 (Apr 1977) 19 figs, 18 tables, 7 refs

Key Words: Beams, Plates, Natural frequencies

The present paper deals with the analysis of certain dynamic aspects of the behavior of beams and plates which support elastically mounted masses. Shear and rotatory inertia effects are not taken into account in the present investigation. An exact solution is presented in the case of a simply supported beam. This solution can be easily extended to the problem of a simply supported rectangular plate. It is also shown that use of a variational formulation leads to accurate and simple expressions for natural frequencies and dynamic displacements and stresses which are ideal from a designer's viewpoint. The case of supports elastically restrained against rotation is also considered. The experimental phase of the investigation showed good agreement with experimental results.

77-1445

The Influence of Tip Mass on the Stability of a Rotating Cantilever Subjected to Dissipative and Transverse Follower Forces

G.L. Anderson

Applied Mathematics and Mechanics Div., Watervliet Arsenal, Watervliet, NY 12189, Meccanica, 11 (2), pp 89-97 (June 1976) 13 figs, 9 refs

Key Words: Cantilever beams, Mass-beam systems, Rotors, Rotatory inertia effects, Follower forces

The state of stability of a rotating viscoelastic cantilever beam subjected to a transverse follower force applied at its free end in the plane of rotation is determined by a method of approximation that is based upon an adjoint variational principle. Particular attention is devoted to the determination of the dependence of the critical flutter load of the system on the transverse, twisting, and rotary inertia properties of a mass capping the free end of the beam. The equations of motion are derived from a conservation law, the adjoint boundary value problem is introduced, and an approximate stability determinant is developed from the variational principle upon assuming a set of coordinate functions which satisfy a selected set of boundary conditions. The stability determinant is solved numerically for a variety of choices of values for the internal damping, the hub radius, tip mass inertia, the rotational speed, and warping rigidity parameters, and several graphs are presented to show the influence of these parameters upon the value of the critical flutter load.

77-1446

Energetic Characteristic of Necessary Optimality Conditions

V.B. Grinev and A.P. Filippov

Lockheed Missiles and Space Co., Palo Alto, CA, 3 pp (1976) (Engl. transl. from: "Optimizatsiya Elementov Konstruktsii po Mekhanicheskim Kharakteristikam" Kiev, Naukova Dumka Press, 1975, pp 50-54)

N77-17511

Key Words: Rods, Longitudinal response, Natural frequencies

Starting with a notation for the potential and kinetic energies of a strained rod, the differential equation of free longitudinal vibrations is obtained for the stationary condition of the Ostrogradskii-Hamilton function. The equations for the configuration for natural frequencies, and the equations for the amplitude value of the potential and kinetic energies per unit of the rod are derived.

77-1447

Equilibrium and Stability of a Whirling Rod-Mass System

J.J. Russell and W.J. Anderson

U.S. Air Force Academy, Colorado Springs, CO 80840, Intl. J. Nonlinear Mech., 12 (2), pp 91-101 (1977) 8 figs, 6 refs

Key Words: Whirling, Towed bodies, Cables, Multi-degree-of-freedom systems, Lumped mass method

A two-degree-of-freedom lumped-mass model is used to gain understanding of the equilibrium and stability of a circularly towed cable. Particular cases considered are those of no drag, viscous drag, and viscous drag with a crosswind.

BEARINGS

77-1448

Vibrational Characteristics of Ball Bearings

P.K. Gupta, L.W. Winn, and D.F. Wilcock

Mechanical Technology, Inc., Latham, NY 12110, J. Lubric. Tech., Trans. ASME, 99 (2), pp 284-289 (Apr 1977) 6 figs, 5 refs

Key Words: Ball bearings, Natural frequencies

The classical differential equations of motion of the ball mass center in an angular contact thrust loaded ball bearing are integrated with prescribed initial conditions in order to simulate the natural high frequency vibrational characteristics of the general motion. Two distinct frequencies are identified in the analytical simulation and their existence is also confirmed experimentally.

77-1449

Systems of Finite Elements for Finite Bearings

P.E. Allaire, J.C. Nicholas, and E.J. Gunter

Dept. of Mech. Engrg., Univ. of Virginia, Charlottesville, VA, J. Lubric. Tech., Trans. ASME, 99 (2), pp 187-198 (Apr 1977) 6 figs, 4 tables, 19 refs

Key Words: Bearings, Slider bearings, Journal bearings, Finite element technique

Systems of finite elements are organized using matrix notation for finite length bearings. Most fluid film bearings have surface areas which can be divided into a grid of elements whose nodes are labeled in matrix form. The resulting equations for nodal pressures are block tridiagonal and the solution is easily obtained with direct methods. Analysis of both general slider and journal bearings is included.

77-1450

Analysis of the Stiffness and Damping Characteristics of an Externally Pressurized Porous Gas Journal Bearing

N.S. Rao

Dept. of Mech. Engrg., Indian Inst. of Tech., Kharagpur, India, J. Lubric. Tech., Trans. ASME, 99 (2), pp 295-301 (Apr 1977) 9 figs, 11 refs

Key Words: Journal bearings, Stiffness coefficients, Damping coefficients

The dynamic behavior of an externally pressurized porous gas journal bearing is analyzed by assuming one dimensional flow through porous wall. A periodic (displacement) disturbance is imposed on the bearing, and the dynamic pressure distribution is determined by small perturbations of the Reynolds equation. Stiffness and damping for various design conditions are calculated numerically using a digital computer and presented in the form of design charts and tables.

77-1451

Journal Bearing Impedance Descriptions for Rotordynamic Applications

D. Childs, H. Moes, and H. van Leeuwen

Dept. of Mech. Engrg., Tech. Univ. Twente, Enchede, The Netherlands, J. Lubric. Tech., Trans. ASME, 99 (2), pp 198-214 (Apr 1977) 13 figs, 27 refs

Key Words: Journal bearings, Impedance, Damping, Mathematical models

Bearing impedance vectors are introduced for plain journal bearings which define the bearing reaction force components as a function of the bearing motion. Impedance descriptions are developed directly for the approximate Ocvirk (short) and Sommerfeld (long) bearing solutions. The impedance vector magnitude and the mobility vector magnitude of Booker are shown to be reciprocals. The transformation relationships between mobilities and impedance are derived and used to define impedance vectors for a number of existing mobility vectors including the finite-length mobility vectors developed by Moes.

77-1452

Steady State and Stability Characteristics of a Hydrodynamic Journal Bearing with a Non-Newtonian Lubricant

S.T.N. Swamy, B.S. Prabhu, and B.V.A. Rao

Machine Dynamics Lab., Dept. of Applied Mechanics, Indian Institute of Tech., Madras 600036, India, Wear, 42, pp 229-244 (1977)

Key Words: Journal bearings, Lubrication, Periodic response

The effect of the non-Newtonian behavior of lubricants, resulting from the addition of polymers, on the performance of hydrodynamic journal bearings was investigated. An empirical fluid flow equation which adequately represents the flow behavior of lubricant was used to obtain a modified form of Reynolds' equation. Finite difference numerical solutions were obtained for steady state conditions at various width-to-diameter ratios.

77-1453

Translational Energy Exchanged Between an Oil Film and a Cyclically Loaded Journal - A Theoretical Study

H. McCallion and D.R. Wales

Univ. of Canterbury, New Zealand, Inst. Mech. Engr. Proc., 190 (55), pp 635-641 (1976) 4 figs, 1 table, 3 refs

Key Words: Rotor-bearing systems, Whirling, Journal bearings, Lubrication

Predicting the stability of rotating systems at intermediate and large whirl amplitudes is costly. This paper suggests a cheaper approximate method based upon an overall energy balance. By representing the force exerted on the bearings as combinations of constant forces and cyclically varying forces, the influence of bearing geometry, and other factors on the magnitude and direction of the energy flow between oil film and rotor for a complete cycle was investigated and found significant.

77-1454

Effect of Unbalance on a Journal Bearing Undergoing Oil Whirl

L.E. Barrett, A. Akers, and E.J. Gunter
Univ. of Virginia, Charlottesville, VA, Instn. Mech. Engr. Proc., 190 (31), pp 535-543 (1976) 10 figs, 17 refs

Key Words: Whirling, Lubrication, Journal bearings

A time-transient nonlinear analysis has been developed to examine the dynamical limit cycle motion of a plain journal bearing. The effect of unbalance and ambient pressure on the journal limit cycle motion below and above the linearized stability threshold speed is examined. The short bearing approximation is used, and the assumption of a 180 degree oil film has been relaxed. An arbitrary film extent based upon the instantaneous values of journal displacement, velocity, and ambient pressure is used, and results are discussed in this paper.

77-1455

The Influence of Oil Lubricated Journal Bearings on the Dynamics of Rotating Systems

H. McCallion and D.R. Wales
Univ. of Canterbury, New Zealand, Instn. Mech. Engr. Proc., 190 (54), pp 627-633 (1976) 5 figs, 15 refs

Key Words: Journal bearings, Rotor-bearing systems, Whirling, Lubrication, Computer programs

A computer program representing a shaft and rotor whirling in bearings which allows for realistic oil film boundary conditions and non-circular bearing profiles has been developed. It gave good agreement with experimental results published by Brown and France. With the aim of increasing understanding of the influence of bearing profile on system instability, the program calculates the timewise variation of the energy in translational motion supplied to the rotor by oil film forces. One case is illustrated.

BLADES

(Also see No. 1437)

77-1456

Vibration of Impellers, Part 1. Theoretical Analysis and Experiment of Vibration of Blades

A. Nagamatsu, S. Michimura, and A. Ishihara
Tokyo Institute of Tech., Tokyo, Japan, Bull. JSME, 20 (142), pp 411-418, 11 figs, 5 tables, 21 refs (Apr 1977)

Key Words: Blades, Free vibration, Finite element technique, Shells, Vibration tests, Holographic techniques

Free vibration of impellers of rotating hydromachines is analyzed by both the finite element method and the experiment. An isoparametric, thick shell element is used in the analysis, which allows arbitrary changes in the shape, the thickness and the curvature. The eigenvalue problem is solved with the subspace iteration method. The calculated values of the frequency and the natural mode are in good agreement with the experimental ones.

77-1457

Dynamic Response of Nonuniform Rotor Blades

D.G. Fertis
Dept. of Civil Engrg., Akron Univ., OH, 27 pp (July 28, 1975)
N77-13003/7GA

Key Words: Rotor blades, Helicopter blades, Dynamic response

This paper presents theoretical investigations related to the theory of rotating blades, such as helicopter blades. The works presented here are more general than the ones by other investigators because it takes into consideration that the plane of rotation of the blade is not perpendicular to the axis about which the blade rotates, and that discontinuties along the elastic axis, as well as supporting shaft flexibility, may be also taken into consideration. The general differential equations of rotating pretwisted blades under arbitrary loading and the tedious general expressions for the quantities involved in these equations have been derived here. The aerodynamic loadings, however, are left in general form.

77-1458

Optical Determination of Rotating Fan Blade Deflections

H. Stargardter
Pratt & Whitney Aircraft, East Hartford, CT, J. Engr. Power, Trans. ASME, 99 (2), pp 204-210 (Apr 1977) 15 figs, 4 refs

Key Words: Fans, Compressor blades, Blades, Flutter

Measurement of flutter motion for rotating fan and compressor blades is necessary to verify mode shape analysis and assure an accurate description of the deflection and twist distribution required for stability prediction. The static deflection of blades caused by centrifugal and gas loads also needs to be measured to improve the accuracy of performance analysis. This paper presents a new technique for making these measurements with small blade-mounted mirrors that reflect laser light once per revolution. Vibration amplitude, phase, and frequency are discussed and related to analysis. Limits in accuracy and the importance of precise mode shape description for flutter analysis are presented.

77-1459

The Response of Turbomachine Blades to Low Frequency Inlet Distortions

J.H. Horlock, E.M. Greitzer, and R.E. Henderson
Univ. of Salford, Salford, UK, J. Engr. Power, Trans. ASME, 99 (2), pp 195-203 (Apr 1977) 8 figs, 17 refs

Key Words: Blades, Turbomachinery, Fluid-induced excitation

An analysis is presented of the unsteady lift on a cascade of airfoils moving through a circumferential inlet flow distortion. The flow model is based on blades of finite chord, but small pitch/chord ratio. Two separate methods are used to derive the unsteady lift on the blades, leading to the same analytical expressions in both cases. The analytical solution is compared with earlier investigations of the flow past isolated airfoils (Sears), with numerical results for airfoils in a cascade (Henderson/Daneshyar, Whitehead and Smith) and with actuator disk results. It is shown that the present simple model provides results that are consistent with the numerical calculations for small pitch/chord ratios. In addition, the present method provides a means for resolving a discrepancy between existing theories as to the behavior of the cascade lift coefficient at low reduced frequency.

DUCTS

(Also see No. 1509)

77-1460

Shock Loss Calculations Across Junctions and Splits

J.C. Edwards and H.E. Perlee
Bureau of Mines Publ. No. RI 8227, 9 pp (1977) 6 figs, Avail: Publ. Distr. Branch, Bu. of Mines, U.S. Dept. of Interior, 4800 Forbes Ave, Pittsburgh, PA

Key Words: Ducts, Shock wave propagation, Computer programs

A computer code for laminar, steady-state, incompressible, two-dimensional flow developed by Gosman was modified by the Bureau of Mines to calculate shock (minor) loss at the intersections of ventilation ducts. Turbulent flow was simulated using laminar flow equations and an appropriate wall shear stress. Results of the calculation showed good agreement with the experiment.

77-1461

Advanced Inlet Duct Noise Reduction Concepts

D. Chestnutt and C.E. Feiler
Langley Res. Center., NASA, Langley Station, VA, In: NASA, Langley Res. Center Aircraft Safety and Operating Problems, pp 481-496 (1976)(N77-18081) N77-18107

Key Words: Ducts, Acoustic liners, Aircraft noise

A progress report is given on the implications of inlet noise reduction on aircraft direct operating costs (DOC). It considers treated inlet rings, various other inlet noise reduction concepts, and forward-speed effects. The report was limited to relatively well-established approaches to inlet noise reduction, such as acoustic liners and fixed-geometry/high-subsonic-speed inlets which are the focus of considerable current research activity. All of the concepts discussed are of a 'passive' nature, i.e., no moving parts or electrical feedback systems.

GEARS

77-1462

Noise Control in Bevel Gears

D.R. Carlson and K.W. Evans
SAE Paper No. 770563, 12 pp, 8 figs, 8 refs

Key Words: Gears, Noise reduction

Vibrations created by the meshing action of bevel gears operating in a drive system often result in gear noise. Although this noise is a system problem, it can be reduced at the source by careful design and manufacturing techniques. This paper discusses key factors in these areas.

77-1463

Eliminating an Annoying Whistle from a Spur Gear Power Train

R.F. Holton
Pay Line Div., International Harvester Co., SAE Paper No. 770562, 16 pp, 17 figs, 3 tables, 5 refs

Key Words: Gears, Noise reduction

This paper discusses a methodology and associated logic which can be used to analyze a spur gear power train for sound reduction at the source of generation. The specific example discussed here involves the successful elimination of an intolerable whistle produced by the spur gear transmission of a large crawler tractor.

LINKAGES

77-1464

What is a Flexible Coupling?

N. J. Johnstone

Lovejoy, Inc., Downers Grove, IL 60515, Power Transm. Des., 19 (5), pp 37-40 (May 1977) 12 refs

Key Words: Flexible couplings

Because zero shaft misalignment is unattainable, a coupling must have some flexibility. However, flexible couplings have other functions than compensating for shaft misalignment. These functions and various types of flexible couplings are described.

77-1465

Computer-Aided Synthesis of Linkages -- A Motorcycle Design Study

K. Oldham and J.N. Fawcett

Dept. of Mech. Engrg., Univ. of Newcastle-upon-Tyne, UK, Instn. Mech. Engr. Proc., 190 (31), pp 713-720 (1976) 8 figs, 1 table, 2 refs

Key Words: Suspension systems (automotive), Computer-aided techniques, Motorcycles

The geometry of current motorcycle rear suspension systems is such that the center distance between the gearbox output sprocket and the rear wheel sprocket varies as the suspension deflects. This paper describes the application of a computer program for the synthesis of linkages to the design of a six-bar linkage arrangement.

MEMBRANES, FILMS, AND WEBS

77-1466

On the Response of an Elastic Membrane to a Travelling Ring Load

D.H.Y. Yen and J. Gaffney

Div. of Engrg. Res. and Dept. of Mathematics, Michigan State Univ., East Lansing, MI 48824, Intl. J. Solids Struc., 13 (5), pp 457-466 (1977) 6 figs, 5 refs

Key Words: Membranes, Moving loads

Exact solutions in closed-form are presented for the dynamic response of an infinite elastic membrane to a suddenly applied, radially expanding ring load.

PANELS

(See No. 1429)

PIPES AND TUBES

77-1467

Two-Phase-Flow-Induced Vibrations in a Horizontal Piping System

F. Hara

Faculty of Engrg., Tokyo Univ. of Science, Tokyo, Japan, Bull. JSME, 20 (142), pp 419-427 (Apr 1977) 11 figs, 7 tables, 9 refs

Key Words: Pipes (tubes), Fluid-induced excitation

This paper deals with experimental and theoretical analyses of the excitation mechanism of vibrations induced by an air-and-water two-phase flow in a straight horizontal pipe. The experiment reveals a strong relationship between the first natural frequency of a piping system and the dominant frequency of void-signals when extraordinarily strong vibrations are observed. The equation of motion in a straight horizontal pipe conveying a two-phase fluid is derived by accounting for inertia force; the pipe's elastic restoring force; Coriolis' force; centrifugal force; pressure fluctuations; momentum change due to time-varying density of the two-phase flow and gravity as an external force.

77-1468

Chart for Estimating the Efficiency of the Broadband Sound-Power Radiation by Randomly Vibrating Pipe Walls

W.C. Kennedy and F.J. Young

Gannon College, Erie, PA 16501, J. Acoust. Soc. Amer., 61 (5), pp 1209-1212 (May 1977) 3 figs, 1 table, 8 refs

Key Words: Piping systems, Random excitation, Sound transmission

A general curve is derived for the braodband radiation efficiency of a pipe where walls undergo random vibration. Once the mean amplitude of vibration of the pipe wall is known one can use this curve to predict the broadband sound power level radiated by the pipe.

77-1469

Hydrostatic Transmission Noise Abatement

G.E. Maroney and D.L. O'Neal

Fluid Power Res. Ctr., Oklahoma State Univ., SAE Paper No. 770560, 12 pp, 11 figs, 2 tables, 15 refs

Key Words: Power transmission systems, Noise reduction, Fluid-induced excitation, Pipes (tubes)

This paper discusses the control of the three types of noise associated with hydrostatic transmissions -- airborne, structureborne, and fluidborne. Basic control techniques for all three sources of noise are discussed. Specific guidance for controlling fluidborne noise is provided by discussing the selection of pumps and motors based on flow ripple and impedance, the selection of operational parameters, and the use of fluidborne noise attenuators.

PLATES AND SHELLS

(Also see Nos. 1421, 1431, 1444)

77-1470

Damping Characteristics of 185-Inch "VITSS" and Standard Sonar Dome Structures

H.N. Phelps, Jr.

Navy Underwater Sound Lab., New London, CT, Rept. No. USL-TM-2133-1213-66, 58 pp (Dec 8, 1966)

AD-A035 892/9GA

Key Words: Domes, Sonar, Damping coefficients

This technical memorandum presents the damping and vibration characteristics, measured in air, of a 185-inch Variable-Internal-Truss-Sizes-and Spacing (VITSS) Steel Sonar Dome Structure, without window. Results are compared with a standard 185-inch CW554/SQS steel sonar dome structure, without a window.

77-1471

Numerical Analysis of the Dynamic Response of Elasto-Plastic Shells

M.P. Bieniek, J. Funaro, and M.L. Baron

Weidlinger Associates, NY, Rept. No. TR-20, 69 pp (Nov 1976)

AD-A035 965/3GA

Key Words: Shells, Dynamic buckling, Elasto-plastic properties, Numerical analysis

An efficient numerical procedure for the transient dynamic analysis of the elasto-plastic shells is introduced. A simple shell is analyzed and the results achieved are compared against an existing code.

77-1472

Vibrations of Cross-Supported Viscoelastic Plates

K. Nagaya

Faculty of Engrg., Yamagata Univ., Jyonan, Yonezawa, Japan, J. Acoust. Soc. Amer., 61 (5), pp 1191-1197 (May 1977) 9 figs, 12 refs

Key Words: Plates, Viscoelastic properties

This paper discusses a free- and a forced-vibration problem of elastically cross-supported rectangular viscoelastic plate with various edge conditions. A three-elements viscoelastic model is adopted in the analysis. The result for the viscoelastic plate is obtained from the correspondence principle by applying the Laplace transform to the constitutive equation for the viscoelastic materials and to the equation of motion in terms of unknown forces which are equivalent to reaction forces and resisting moments of the supports. Some numerical results are shown for steady-state and transient response problems.

77-1473

Dynamic Analysis of a Plate Heat Exchanger System

H. Masubuchi and A. Ito

Faculty of Engrg., Osaka Univ., Suita, Japan, Bull. JSME, 20 (142), pp 434-441 (Apr 1977) 5 figs, 2 tables, 11 refs

Key Words: Heat exchangers, Plates, Thermal excitation

This paper presents a systematic analysis of static and dynamic characteristics of plate heat exchangers having a number of heat transfer plates. There are various flow types in a plate heat exchanger system. The results are numerically compared under the condition that each flow rate of the hot- and cold-side fluids remains constant, respectively in any flow type.

SPRINGS

77-1474

The Dynamic Coupling of Torsional and Flexural Strains in Cylindrical Helical Springs

L. Della Pietra

Instituto di Meccanica applicata alle Macchine, Università di Napoli, Italy, Meccanica, 11 (2), pp 102-119 (June 1976) 21 figs, 3 tables, 20 refs

Key Words: Helical springs, Coupled response, Torsional response, Flexural response

The coupling between torsional and flexural strains in cylindrical helical springs axially excited was examined in this paper, both theoretically and experimentally.

STRUCTURAL

77-1475

Optimum Design of Bridge Girders of Electric Overhead Travelling Cranes

S.S. Rao

Indian Inst. of Tech., Kanpur, India, ASME Paper No. 76-WA/DE-28

Key Words: Overhead cranes, Girders, Optimization, Shock absorption

The problem of the design of box-type bridge girders for electric overhead traveling cranes is formulated as a minimum weight design problem with inequality constraints. The restrictions placed on the design problem include limitations on the maximum allowable deflections and stresses as well as on the shock-absorbing capacity during accidental collision. The overall stability and rigidity considerations are also taken into account. Several load conditions, as per the code specifications, are considered in the design problem. The resulting nonlinear programming problem is solved by using an interior penalty function method. Numerical examples are given to illustrate the effectiveness of the approach.

TIRES

77-1476

Tire Parameter Determination. Volume I. Summary

D.S. Schuring

Calspan Corp., Buffalo, NY, Rept. No. CALSPAN-ZM-5563 (1976) (Also available in a set of 9 reports, PB 263-439-SET)

PB-263 440

Key Words: Automobile tires, Truck tires, Tire characteristics, Computerized simulation, Mathematical models, Experimental data

The objective of this study was to generate a comprehensive body of the major force and moment characteristics of passenger car and light truck tires currently distributed in the USA, and to present them in a form suitable for vehicle handling computer simulations.

77-1477

Effects of Tire Properties on Truck and Bus Handling. Appendix C. Volume II

R.D. Ervin, C.B. Winkler, J.E. Bernard, and R.K. Gupta

Highway Safety Res. Inst., Michigan Univ., Ann Arbor, MI, Rept. No. UM-HSRI-76-11 (Dec 1976) (Also available in a set of 4 reports, PB-263-877-SET)

PB-263 879

Key Words: Truck tires, Tire characteristics, Trucks, Buses (vehicles)

The project identifies the importance of tire traction properties of truck tires in order to determine the steering and braking response of light and heavy commercial vehicles. Tire tests on a large sample of light and heavy truck tires were conducted using two laboratory and one over-the-road tire test device. A computerized simulation study providing a mechanistic understanding of the response sensitivity of the open-loop vehicle to tire properties was conducted.

77-1478

The Steering Characteristics of Multiple Axle Bogie Systems

J.R. Ellis

School of Automotive Studies, Cranfield Inst. of Tech., UK, Vehicle Syst. Dyn., 5 (4), pp 221-238 (Dec 1976) 13 figs

Key Words: Commercial transportation, Articulated vehicles, Tire characteristics, Steering effects

Legislation limits the load that may be transferred to the roadway by the axles of a commercial vehicle and this has resulted in the development of multi axle bogies for both the tractor and trailer units of articulated vehicles and at the rear of rigid vehicles, some of these bogies contain self steering or articulation steered axles. Experience shows that the tire wear characteristics of multi axle bogies may be unsatisfactory. The paper analyzes the role of such bogies in the context of vehicle handling and shows how the lateral tire forces vary between the axles. An hypotheses relating the forces in a steady state turn to wear is given. The analysis may also be applied to the general case of vehicle handling.

SYSTEMS

ABSORBER

77-1479

Viscously Damped Dynamic Absorbers of Conventional and Novel Design

M.A. Nobile and J.C. Snowdon

Applied Res. Lab., Penn. State Univ., University Park, PA, Rept. No. TM-76-308, 52 pp (Dec 10, 1976) AD-A036 684/9GA

Key Words: Dynamic vibration absorption (equipment)

The behavior of dynamic vibration absorbers of conventional and novel design has been investigated experimentally and found to compare closely with prediction. The dynamic absorbers were employed to suppress the transmissibility at resonance across a one-degree-of-freedom primary system. Results are discussed in this paper.

77-1480

Viscously Damped Dynamic Absorbers of Conventional and Novel Design

M.A. Nobile and J.C. Snowdon

Applied Res. Lab., Penn State Univ., University Park, PA 16802, J. Acoust. Soc. Amer., 61 (5), pp 1198-1208 (May 1977) 17 figs, 19 refs

Key Words: Dynamic vibration absorption (equipment), Vibration absorption (equipment)

The behavior of dynamic vibration absorbers of conventional and novel design has been investigated experimentally and found to compare closely with prediction. The dynamic absorbers were employed to suppress the transmissibility at resonance across a one-degree-of-freedom primary system. Results are discussed in this paper.

77-1481

Perforated Facings Backed with Porous Materials as Sound Absorbers -- An Experimental Study

W.A. Davern

Div. of Building Res., CSIRO, Melbourne, Australia, Applied Acoustics, 10 (2), pp 85-112 (Apr 1977) 11 figs, 7 refs

Key Words: Absorbers (materials), Hole-containing media

This paper describes how the physical elements of a perforated facing backed with a porous material sound absorbent system -- percentage perforation and thickness of the facing, the density of the porous backing material and the arrangement of the facing in relation to the backing material -- can change the specific acoustic impedance of the absorber and hence its absorption coefficient. These factors can then be used in achieving a good design.

77-1482

Experimental Investigation of Noise Radiation From a Circular Plate Covered by Polyurethane Foam

M.A. Satter and G. Ahmadi

Dept. of Mech. Engrg., Pahlavi Univ., Shiraz, Iran, Applied Acoustics, 10 (2), pp 113-120 (Apr 1977) 2 figs, 2 tables, 15 refs

Key Words: Absorbers (materials), Foams, Noise reduction

An experimental investigation of the noise reduction achieved by covering a thin circular plate is reported. The plate boundary was unconstrained. One side of the plate was covered by sound-absorbing material so that noise radiation from the other side for different configurations of foam cover was measured and compared with the noise level obtained without any foam cover.

77-1483

Demonstration of Procedure for Designing Impact-Bag Attenuation Systems with Predictable Performance

F.J. Stimler

Goodyear Aerospace Corp., Akron, OH, J. Aircraft, 14 (5), pp 502-507 (May 1977) 21 figs, 4 refs

Key Words: Air bags (soft landing), Mathematical models, Computer programs, Drop tests, Energy absorption

A six-degree-of-freedom mathematical model and computer

program were used to predict the performance of a rectangular-shaped impact-bag attenuation system that was designed and fabricated for drop-testing an MQM-34D remotely piloted vehicle (RPV). The impact bag was a lightweight structure without internal supports and having reliable, repeatable bag-pressure relief orifices. Elastometric materials suitable for the total temperature environment were used. Bag pressures and RPV loads were predicted for both vertical and horizontal velocity components.

NOISE REDUCTION

(Also see Nos. 1461, 1462, 1463, 1469, 1481, 1482, 1491, 1510, 1519, 1520)

77-1484

How to Select Effective Lagging Configurations

G.E. Johnson

Tennessee Eastman Co., Kingsport, TN, S/V, Sound Vib., 11 (4), pp 34-35 (Apr 1977) 4 figs, 5 refs

Key Words: Noise reduction, Lagging

The application of an acoustically absorbent blanket covered with an impermeable barrier to the surface of a noise source for the purpose of noise reduction is termed "lagging." It is well known that airborne sound transmission loss data cannot be used to predict noise reductions for lagging configurations, particularly when the noise source contains significant low frequency content. A design procedure is outlined to aid in the selection of an effective lagging configuration for the lowest octave band of interest.

77-1485

The Operation of Murphy's Laws in Noise Control Engineering

S.R. Wade

Hayes, Seay, Mattern and Mattern, P.O. Box 13446, Roanoke, VA 24034, Noise Control Engr., 8 (1), pp 24-26 (Jan/Feb 1977) 3 refs

Key Words: Noise control

While much has been published in technical journals on the applications of advanced mathematics to theoretical acoustics and noise control, there are few references to the operation of Murphy's Laws. The author illustrates the relevance of these laws to familiar noise problems.

77-1486

Noise Control by Barriers -- Part 1: Noise Reduction by a Thick Barrier

K. Fujiwara, Y. Ando, and Z. Maekawa

Kyushu Inst. of Design, Fukuoka, Kyushu 815, Japan, Applied Acoustics, 10 (2), pp 147-159 (Apr 1977) 10 figs, 11 refs

Key Words: Noise barriers, Noise reduction

This paper presents a method of estimating the excess attenuation of noise by a thick barrier. In this method, the excess attenuation of noise by a thick barrier is assumed to be composed of two parts, one being the effect of a virtual thin barrier with the same height and the other the effect of thickness. A single chart for estimating this thickness effect is offered under conditions which only permit an error of a few decibels. The validity of the method presented here is verified by comparing the estimated with the measured values. Consequently, this method may be useful for the purpose of estimating the excess attenuation of a band of noise by the barrier whose thickness is larger than half a wavelength.

77-1487

The Protection of Buildings Against Traffic Noise

F.R. Fricke

Dept. of Architectural Science, Univ. of Sydney, New South Wales 2006, Australia, Noise Control Engr., 8 (1), pp 27-32 (Jan/Feb 1977) 10 figs, 15 refs

Key Words: Noise reduction, Noise barriers

The use of walls or barriers for controlling noise has been appreciated for many years. However, their applicability to situations in which buildings are located near busy roads is strictly limited by a number of factors. The results of model investigations for three alternatives to the conventional barrier are presented. These alternatives appear to offer improved acoustics, economics, and aesthetics.

77-1488

Control of Pneumatic Chipping and Grinding Noise

A. Visnapuu and J.W. Jensen

Bureau of Mines Publ. No. RI 8223, 16 pp (1977) 5 figs, Avail: Publ. Distr. Branch, Bu. of Mines, U.S. Dept. of Interior, 4800 Forbes Ave, Pittsburgh, PA 15213

Key Words: Tools, Noise reduction

Pneumatic chipping, scaling, and grinding can expose the tool operator to noise levels in the range 90 to 120 dbA. In most chipping and scaling operations, casting resonance is the primary source of noise, followed by air exhaust, and machine and chisel resonance. In grinding, the air-exhaust noise

predominates. The Bureau of Mines has shown that noise from these operations can be reduced by up to 15 dbA.

77-1489
The Use of Plasterboard and Wood Wool in Industrial Noise Control
P.E. Jones and P. Royle
Res. and Dev. Dept., British Gypsum, Ltd., Noise Control, Vib. and Insul., 8 (4), pp 117-119 (Apr 1977) 5 figs

Key Words: Noise reduction, Buildings

Some applications of plasterboard and wood wool in industrial noise control are given. Any specific sound insulation results quoted have been obtained in the laboratory to BS 2750 and ISO R140.

ACTIVE ISOLATION

77-1490
An Active Suspension with Optimal Linear State Feedback
A.G. Thompson
Dept. of Mech. Engrg., Univ. of Adelaide, South Australia, Vehicle Syst. Dyn., 5 (4), pp 187-203 (Dec 1976) 5 figs, 2 tables, 14 refs

Key Words: Active isolation, Suspension systems (vehicles), Ground vehicles

In this paper modern optimal control theory is applied to the design of an active suspension system for a motor vehicle. The road profile is assumed to be continuous and random with a power spectral density (P.S.D.) which varies inversely with the square of the frequency. The quadratic integral type performance index employed is a weighted sum of the integral squares of body acceleration, dynamic tire deflection and relative body-to-axle displacement. A solution is obtained for the infinite time case which is both computationally and physically realizable as an active suspension in which the only continuous measurements required are the body absolute velocity and the body displacement relative to the road. The performance is compared with that of a conventional type passive suspension and found to be significantly better in practically all respects.

AIRCRAFT
(Also see No. 1441)

77-1491
Interior Noise Analysis and Control for Light Aircraft
J.S. Mixson, C.K. Barton, and R. Vaicaitis
Langley Res. Center, NASA, Langley Station, VA., SAE Paper No. 770445, 12 pp, 14 figs, 18 refs

Key Words: Noise reduction, Aircraft noise

This paper describes experimental and analytical studies of the interior noise of twin-engine, propeller-driven, light aircraft. The analytical model described uses modal methods and incorporates the flat-sided geometrical and skin-stringer structural features of light aircraft. Initial results show good agreement with measured noise transmitted into a rectangular box through a flat panel.

77-1492
Airframe Noise: A Design and Operating Problem
J.C. Hardin
Langley Res. Center, NASA, Langley Station, VA., In: NASA, Langley Res. Center Aircraft Safety and Operating Problems, pp 527-550 (1976)(N77-18081)
N77-18110

Key Words: Aircraft noise, Airframes, Panels

A critical assessment of the state of the art in airframe noise is presented. Full-scale data on the intensity, spectra, and directivity of this noise source are evaluated. Vibration of panels on the aircraft is identified as a possible additional source of airframe noise. The present understanding and methods for prediction of other component sources - airfoils, struts, and cavities - are discussed. Operating problems associated with airframe noise as well as potential design methods for airframe noise reduction are identified.

77-1493
Coannular Nozzle Noise Characteristics and Application to Advanced Supersonic Transport Engines
H. Kozlowski
Pratt and Whitney Aircraft Group, West Palm Beach, FL, In: NASA, Langley Res. Center Proc. of the Supersonic Cruise Aircraft (SCAR) Conf., Pt. 2, 14 pp (1976) refs (N77-18019)
N77-18021

Key Words: Supersonic aircraft, Aircraft noise, Noise generation

Recent programs in the field of jet noise, sponsored by the NASA Lewis Research Center, have indicated that the variable stream control engines (VSCE) which are being considered for advanced supersonic cruise aircraft have inherent

jet noise advantages over earlier engines. This report is concerned with scale model tests, cycle changes, and operation modes to determine the levels of jet noise.

77-1494

Coannular Plug Nozzle Noise Reduction and Impact of Exhaust System Designs

R. Lee

Aircraft Engine Group, General Electric Co., Philadelphia, PA, In: NASA, Langley Res. Center Proc. of the Supersonic Cruise Aircraft (SCAR) Conf., Pt. 2, 20 pp (1976) (N77-18019)

N77-18022

Key Words: Supersonic aircraft, Aircraft noise, Noise reduction

Reducing the noise generated by high velocity jets has confronted engine designers and acoustics workers alike for the past fifteen years. Some of the jet noise suppressor configurations that are investigated are shown. This work pertains to the concept demonstration and scale model testing of coannular plug nozzles with inverted velocity profile, and to the preliminary study of its application to advanced variable cycle engines (VCE) appropriate for supersonic cruise aircraft.

77-1495

Current Research in Sonic-Boom Minimization

C.M. Darden and R.J. Mack

Langley Res. Center, NASA, Langley Station, VA., In: NASA, Langley Res. Center Proc. of the Supersonic Cruise Aircraft (SCAR) Conf., Pt. 2, 17 pp (1976) refs (N77-18019)

N77-18023

Key Words: Reviews, Supersonic aricraft, Aircraft noise, Sonic boom, Noise reduction

A review is given of several questions as yet unanswered in the area of sonic-boom research. Efforts in the area of minimization, human response, design techniques and in developing higher order propagation methods are discussed. In addition, a wind-tunnel test program being conducted to assess the validity of minimization methods based on a forward spike in the F-function is described.

77-1496

Evaluation of Methods of Reducing Community Noise Impact Around San Jose Municipal Airport

J.M. Glick, R.S. Shevell, and J.V. Bowles

Stanford Univ., CA., Rept. No. NASA-TM-X-73077; A-6346, 64 pp (Nov 1975)

N77-17828

Key Words: Aircraft, Airport noise, Noise reduction, Computerized simulation

A computer simulation of the airport noise impact on the surrounding communities was used to evaluate alternate operational procedures, improved technology, and land use conversion as methods of reducing community noise impact in the airport vicinity. In addition, a constant density population distribution was analyzed for possible application to other airport communities with fairly uniform population densities and similar aircraft operational patterns.

77-1497

Effects of Aircraft Noise on Flight and Ground Structures

J.S. Mixson, W.H. Mayes, and C.M. Willis

Langley Res. Center, NASA, Langley Station, VA., In: NASA, Langley Res. Center Aircraft Safety and Operating Problems, pp 513-526 (1976)(N77-18081)

N77-18109

Key Words: Aircraft noise, Sound transmission, Buildings

Acoustic loads measured on jet-powered STOL configurations are presented for externally blown and upper surface blown flap models ranging in size from a small laboratory model up to a full-scale aircraft model. The implications of the measured loads for potential acoustic fatigue and cabin noise are discussed. Noise transmission characteristics of light aircraft structures are presented. The relative importance of noise transmission paths, such as fuselage sidewall and primary structure, is estimated. Acceleration responses of a historic building and a residential home are presented for flyover noise from subsonic and supersonic aircraft. Possible effects on occupant comfort are assessed.

77-1498

Calculation of Unsteady Subsonic Flow About Harmonically Oscillating Wing/Body Configurations

R. Roos, B. Bennekers, and R.J. Zwaan

National Aerospace Lab NLR, Amsterdam, The Netherlands, J. Aircraft, 14 (5), pp 447-454 (May 1977) 12 figs, 13 refs

Key Words: Aircraft wings, Wing stores, Flutter, Aerodynamic loads

A description is given of a panel method for the calculation of the aerodynamic loading on harmonically oscillating wing/body configurations in subsonic flow. Neglecting their thickness, the loading on the lifting surfaces is assumed to be generated by a distribution of unsteady lifting lines. The loads on the body are represented by an unsteady source panel distribution. A way is indicated to introduce the effect of the steady flow into the unsteady calculations. The method provides local and total coefficients as well as detailed pressure distributions on both the lifting surfaces and the bodies. The applicability of the method is shown in a comparison of calculated and experimental pressure and load distributions on a wing/tip tank/pylon store configuration.

77-1499

Flutter Suppression by Active Control and Its Benefits

R.V. Doggett, Jr. and J.L. Townsend
Langley Res. Center, NASA, Langley Station, VA., In: NASA, Langley Res. Center Proc. of the Supersonic Cruise Aircraft (SCAR) Conf., Pt. 1, pp 303-333 (1976) refs (N77-17996)
N77-18011

Key Words: Aircraft vibration, Supersonic aircraft, Flutter

A general discussion of the airplane applications of active flutter suppression systems is presented with focus on supersonic cruise aircraft configurations. Topics addressed include a brief historical review; benefits, risks, and concerns; methods of application; and applicable configurations. Results are presented where the direct operating costs and performance benefits of an arrow wing supersonic cruise vehicle equipped with an active flutter suppression system are compared with corresponding costs and performance of the same baseline airplane where the flutter deficiency was corrected by passive methods (increases in structural stiffness). The design, synthesis, and conceptual mechanization of the active flutter suppression system are discussed.

77-1500

Cabin Safety by Crash Survival

R.W. Nelson
Federal Aviation Administration, U.S. Dept. of Transportation, SAE Paper No. 770485, 16 pp, 7 figs, 31 refs

Key Words: Crashworthiness, Crash research (aircraft)

This paper briefly traces development of crashworthiness requirements promulgated in pertinent airworthiness standards for general aviation aircraft. Primary emphasis is focused on protection of aircraft occupants in the survivable crash environment.

77-1501

General Aviation Crash Safety Program at Langley Research Center

R.G. Thomson
Langley Res. Center, NASA, Langley Station, VA., In: NASA, Langley Res. Center Aircraft Safety and Operating Problems, pp 369-390 (1976)(N77-18081)
N77-18101

Key Words: Crash research (aircraft), Experimental data, Nonlinear theories, Energy absorption

The purpose of the crash safety program described in this report is to support the development of the technology to define and demonstrate new structural concepts for improved crash safety and occupant survivability in general aviation aircraft. The program involves three basic areas of research: full-scale crash simulation testing, nonlinear structural analyses necessary to predict failure modes and collapse mechanisms of the vehicle, and evaluation of energy absorption concepts for specific component design. Both analytical and experimental methods are being used to develop expertise in these areas. Analyses include both simplified procedures for estimating energy absorption capabilities and more complex computer programs for analysis of general airframe response. Full-scale tests of typical structures as well as tests on structural components are being used to verify the analyses and to demonstrate improved design concepts.

77-1502

Response of A-6 Landing Gear Door to Air Shock Loading

J.G. Connor, Jr.
White Oak Lab., Naval Surface Weapons Center, Silver Spring, MD., Rept. No. NSWC/WOL/TR-76-94, 56 pp (Oct 24, 1976)
AD-A035 459/7GA

Key Words: Aircraft, Landing gear, Doors, Air blast, Finite element technique, Computer programs

Response of an A-6 Aft Main Landing Gear Door to static and transient pressure loads has been calculated with the NASTRAN finite element structural analysis computer code. On the basis of manufacturer's static tests these doors have been considered to be the structural items on the plane most sensitive to shock loading. Displacements calculated for static loading compare favorably with those measured on tests.

BUILDING

(See Nos. 1417, 1497)

HELICOPTERS

(Also see No. 1457)

77-1503

Correlation of AH-1G Helicopter Flight Vibration Data and Tailboom Static Test Data with NASTRAN Analytical Results

J.D. Cronkhite, H.E. Wilson, and V.L. Berry

Bell Helicopter Co., Fort Worth, TX, Rept. No. NASA-CR-145120, 148 pp (1976) refs

N77-18136

Key Words: Helicopters, Vibration response, Computer programs

Level flight airframe vibration at main rotor excitation frequencies was calculated. A NASTRAN tailboom analysis was compared with test data for evaluation of methods used to determine effective skin in a semimonocoque sheet-stringer structure. The flight vibration correlation involved comparison of level flight vibration for two helicopter configurations: clean wing, at light gross weight and wing stores at heavy gross weight. In the tailboom correlation, deflections and internal loads were compared using static test data and a NASTRAN analysis. An iterative procedure was used to determine the amount of effective skin of buckled panels under compression load.

77-1504

The Evaluation of Human Exposure to Helicopter Vibration

M.J. Griffin

Inst. of Sound and Vibration Research, Univ. of Southampton, Southampton S09 5NH, UK, Aeronaut. J., 81 (795), pp 110-123 (Mar 1977) 11 figs, 1 table, 47 refs

Key Words: Helicopter vibration, Human response

In the article a design guide and the isolation of problem areas of human response to helicopter vibrations are discussed. Appendix A to this paper contains the wording of the design guide for crew exposure to helicopter vibration. Appendix B gives worked examples showing how the evaluation procedure may be applied and Appendix C provides an outline record of the process employed to arrive at the form of the guide. The remainder of this paper presents additional background information and some recommendations for future research.

HUMAN

(See No. 1504)

ISOLATION

(Also see No. 1519)

77-1505

Vibration-Resistant Mount for Process Instrument Lines

Nuclear Div., Union Carbide Industrial Corp. Bull. No. 167. (Additional information may be obtained from Union Carbide Corp., Nuclear Div., P.O. Box 1410, Paducah, KY 42001)

Key Words: Mountings, Vibration control

An improved mounting for process instrument lines has been developed. The mounting consists of a small Teflon block secured to a unistrut strip which is tack welded to the process equipment. The Teflon block is grooved to mate with the unistrut and is also grooved in a manner to firmly clamp the instrument lines to the Teflon block. This mounting has been found to be resistant to vibration and temperatures up to 400 degrees F. Use of Teflon allows for expansion and contraction of tubing to minimize instrument line failure. As many instrument lines as practical may be seated in a single mount. The mounting is presently in general use. Potential industrial application could be for mounting instrument lines to vibrating equipment.

77-1506

Aspects of Car Rear Suspension

D. Bastow

Instn. Mech. Engr. Proc., 190 (53), pp 611-626 (1976) 11 figs, 2 tables, 6 refs

Key Words: Suspension systems (vehicles), Design techniques

Various considerations which need to be kept in mind when designing rear axles and independent rear suspensions are listed and explored, so that a sensible compromise related to the vehicle type and desired characteristics can more easily be achieved or approximated at the design stage. Methods of avoiding standing height and bounce frequency variation between one-up and fully laden vehicles are described and illustrated with reference to optional extra and initially incorporated systems. Accepting the desirability of maintaining the same relationship to critical damping over the load range, different ways of achieving it are described.

MATERIAL HANDLING

(See No. 1488)

METAL WORKING AND FORMING

77-1507
The Transport and Breakdown of Solid Lubricants in a Simple Forging Operation
W.R.D. Wilson and S. Lak
Dept. of Mech. Engrg., Univ. of Massachusetts, Amherst, MA., J. Lubric. Tech., Trans. ASME, 99 (2), pp 230-235 (Apr 1977) 8 figs, 6 refs

Key Words: *Lubrication, Forging, Surface roughness*

Aluminum alloy workpieces of different roughness, lubricated with graphite, P.T.F.E., lead or polyethylene, were upset between overhanging dies. Measurements of the width of the unlubricated zone formed at the workpiece edge indicated that the rates of outward transport of the lubricants were increased by roughening the workpiece.

77-1508
Studies on the Forced Vibration during Grinding
T. Shimizu, I. Inasaki, and S. Yonetsu
Faculty of Engrg., Keio Univ., Japan, Bull. JSME, 20 (142), pp 475-482 (Apr 1977) 20 figs, 2 tables, 13 refs

Key Words: Forced vibration, Grinding (material removal), Mathematical models

The purpose of this paper is to investigate the influence of forced vibrations on the geometrical accuracy of ground surface. The methods to calculate the grinding stiffness, the contact stiffness and the effect of geometrical interference between grinding wheel and workpiece which are important factors in grinding are shown and discussed. Considering these factors a model of grinding process is proposed to analyze the vibration problem.

PUMPS, TURBINES, FANS, COMPRESSORS

(Also see Nos. 1426, 1442, 1458)

77-1509
Effects of Acoustic Loading on Axial Flow Fan Noise Generation
P.K. Baade
Acoustics and Dynamics, Res. Div., Carrier Corp., Syracuse, NY 13201, Noise Control Engr., 8 (1), pp 5-15 (Jan/Feb 1977) 13 figs, 26 refs

Key Words: Ducts, Fans, Noise generation, Impedance

Problems associated with practical fan sound power measurements and with estimating the sound power radiated into a duct system are discussed, including the effects of internal fan and duct impedance.

77-1510
Centrifugal Blower Noise Studies Literature Survey and Noise Measurements (Etudes des Bruits Associees a l'Utilisation des Souffleurs Centrifuges Etude de la Litterature Specialisee et Mesures des Bruits)
G. Krishnappa
Div. of Mech. Engrg., National Res. Council of Canada, Ottawa, Canada, Rept. No. DME-ME-244, NRC-15679, 56 pp (Dec 1976)
AD-036 047

Key Words: Fans, Blowers, Noise reduction

A review of the existing literature on the subject of centrifugal fan and blower noise studies is presented in this report to establish further areas of research needed to aid in the development of a quiet blower. Noise measurements on a wide variety of blowers used in the laboratory, ranging from 1/3 to 700 horsepower are described, with the object of identifying important frequency components from various types of blowers.

77-1511
Punch Press Load-Radiation Characteristics
L.L. Koss
Dept. of Mech. Engrg., Monash Univ., Clayton, Victoria 3168, Australia, Noise Control Engr., 8 (1), pp 33-39 (Jan/Feb 1977) 16 figs, 2 tables, 8 refs

Key Words: Presses, Noise generation, Sound transmission

Sound radiation characteristics as a function of blanking load of three different capacity punch presses are described.

RAIL

(Also see No. 1436)

77-1512
Tramway Noise in City Traffic

R. Rylander, M. Björkman, U. Åhrlin, and S. Sörensen

Dept. of Environ. Hygiene, Univ. of Gothenburg, Gothenburg, Sweden, J. Sound Vib., 51 (3), pp 353-358 (Apr 8, 1977) 5 figs, 2 tables, 4 refs

Key Words: Tramways, Noise generation, Human response

The extent of annoyance was studied in populations exposed to various levels of mixed tramway and motor traffic noise. The respondents were able to distinguish between the annoyance caused by the two types of traffic. With an increasing number of heavy vehicles annoyance due to traffic noise increased more than annoyance due to tramway noise in mixed city traffic.

77-1513
Railway Noise Propagation

E.J. Rathe

Swiss Federal Inst. of Technology, Zürich, Switzerland, J. Sound Vib., 51 (3), pp 371-388 (Apr 8, 1977)

Key Words: Railroad trains, Sound transmission

The propagation of railway noise is characterized by the typical arrangement of noise sources on a moving train. The rates of sound attenuation with distance are determined for peak levels and for the equivalent steady sound levels in the cases of omnidirectional, and directional sources. The means of noise control within the path of sound propagation are discussed.

77-1514
Railway Vehicle Internal Noise

P.W. Eade and A.E.J. Hardy

The Railway Tech. Centre, London Road, Derby DE2 8UP, UK, J. Sound Vib., 51 (3), pp 403-415 (Apr 8, 1977) 12 figs, 19 refs

Key Words: Railway vehicles, Noise generation

The mechanisms by which noise reaches the passenger in a rail vehicle are discussed. A summary is given of the basis on which suitable specifications for the interior noise level in a new vehicle can be selected. Methods are described by which the acoustic performance of a rail vehicle can be assessed at the design stage. Areas requiring further investigation, in particular the prediction and control of the structure-borne noise input to a vehicle, are highlighted.

77-1515
Factors Affecting Railway Noise Levels in Residential Areas

J.G. Walker

Inst. of Sound and Vibration Research, Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 51 (3), pp 393-398 (Apr 8, 1977) 2 figs, 4 tables, 8 refs

Key Words: Railroad trains, Noise generation

In order to be able to estimate noise levels in residential areas it is important to understand the mode of propagation of railway noise in open ground conditions. Experiments were conducted to investigate the effect of train type and speed as well as distance from the track on measured noise levels. Data are presented which show the effect of all these parameters and a simple procedure is outlined that allows the maximum noise level at any position is a residential area to be estimated.

77-1516
Railroad and Rail Transit Noise Sources

R. Lotz

Transportation Systems Center, U.S. Dept. of Transportation, Kendall Square, Cambridge, MA 02142, J. Sound Vib., 51 (3), pp 319-336 (Apr 8, 1977) 12 figs, 4 tables, 37 refs

Sponsored by the Urban Mass Transp. Administration

Key Words: Railroad trains, Noise generation

In this paper recently reported measurements of locomotive and railcar noise emission are reviewed and presented for use in making such design predictions. Locomotive noise is largely confined to the range of 75 to 95 dB(A) at 30 m (100 ft) for all speeds.

77-1517
Railway Noise Annoyance in Residential Areas: Current Findings and Suggestions for Future Research

J.M. Fields

Dept. of Social Statistics, Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 51 (3), pp 343-351 (Apr 8, 1977) 3 figs, 1 table, 14 refs

Key Words: Railroad trains, Noise generation, Human response

Five published studies of railway noise annoyance in residential areas are reviewed. All the studies find that annoyance increases with railway noise levels and number of train passages.

77-1518

Noisiness of High Speed Trains

M. Vernet and M. Vallet

Institut de Recherche des Transports, Centre d' Evaluation et de recherche des nuisances, 109, avenue Salvador Allende, 69500 - Bron, France,

J. Sound Vib., 51 (3), pp 359-361 (Apr 8, 1977) 1 fig, 3 tables

Key Words: Railroad trains, Noise generation, Acoustic signatures, Human response

The noise signatures of three types of French trains (Aerotrain I 80, fast train (Rhodanien) and turbotrain) were presented in the laboratory to 24 persons who gave annoyance scores to each of them. The aim of this study was to compare the resulting comfort indices with some acoustic characteristics. The peak-level showed the best correlation with discomfort.

77-1519

Floating Track Slab Isolation for Railways

P. Grootenhuis

Dept. of Mech. Engrg., Imperial College of Science and Technology, London SW7 2BX, UK.,

J. Sound Vib., 51 (3), pp 443-448 (Apr 8, 1977) 6 figs, 7 refs

Key Words: Railroad trains, Noise reduction, Vibration isolation

The disturbance of noise and vibration which can be caused by a railway running through a residential area can be eliminated altogether by boxing the railway in and by providing a floating track slab. Care has to be taken to avoid slab resonance and a most effective type of constrained layer damping technique has been applied in at least two installations. The effectiveness of the floating track slab system has been proven for the cut-and-cover type of construction. A proposed design has been given for a floating track slab inside a bored tunnel without an increase in the tunnel diameter.

77-1520

Prediction and Control of Noise from Railway Bridges and Tracked Transit Elevated Structures

L.G. Kurzweil

Transportation Systems Center, U.S. Dept. of Transportation, Kendall Square, Cambridge, MA 02142,

J. Sound Vib., 51 (3), pp 419-439 (Apr 8, 1977) 3 figs, 2 tables, 24 refs

Key Words: Elevated railroads, Bridges, Rail transportation, Noise prediction, Noise reduction, Mathematical models

This paper reviews the current approaches to the prediction and control of noise radiation from railroad bridges and elevated rail transit structures. The results of noise measurements near a variety of bridge and elevated rail structures are summarized and these structures are rank ordered according to their sideline noise levels. Methods for the control of elevated structure noise are discussed and the results of actual field applications of these treatments are summarized. This article also describes a new analytical model capable of estimating the effects of structural parameters on both vibration transmission within, and noise radiation from, an elevated structure. A sample application of this model is used to evaluate several methods for noise abatement on a composite concrete deck, steel plate girder structure. A set of recommendations for further research are given.

77-1521

Field Measurements of the Vibration Properties of Elevated Rapid Transit Structures

T. Venema and M.L. Silver

Dept. of Materials Engrg., Illinois Univ. at Chicago Circle, Chicago, IL.,

Rept. No. DOT/TST-75/43, 83 pp (Dec 1974)

PB-263 220/6GA

Key Words: Elevated railroads, Vibration measurement

Vibrations induced into rail rapid transit structures may be radiated from the structure as airborne noise that disturbs the rider and the wayside community or as ground-borne vibrations which propagate into the foundations of wayside structures setting walls, floors, and common household items into annoying vibration. This report describes the results of field measurements on existing steel elevated structures presented to aid transit operators and engineers concerned with design, performance, repair, and evaluation of steel elevated rapid transit structures.

REACTORS

77-1522

Finite Element Nonlinear Transient Response Analysis of Simple 2-D Structures Subjected to Impulse or Impact Loads

J.J.A. Rodal and E.A. Witmer

Aeroelastic and Structures Research Lab., Massachusetts Inst. of Technology, Cambridge, MA.,

Rept. No. ASRL-182-1, 269 pp (June 1976)

PB-263 864/1GA

Key Words: Nuclear power plants, Impact response, Finite element technique

This study contributes to the development of practical methods for predicting the large-deflection elastic-plastic transient structural responses of structures which are subjected to transient and impact loads. Application to the structural/operational safety of nuclear power plants is considered. The use of higher-order assumed-displacement finite elements (FE) is investigated to seek more efficient and accurate strain predictions; these studies were carried out for 2-d structural deformations typical of beams and curved rings to minimize cost and labor, using various approximations to the nonlinear strain-displacement relations since large deflections and rotations need to be taken into account. Predictions are made for these various FE models for impulsively-loaded beams and a free initially-circular ring, for which high quality experimental measurements of strains, and deflections are available.

RECIPROCATING MACHINE

77-1523

A Vibrationless Reciprocating Engine (Trial Manufacture and Experiments of a Small Two-Cycle Vibrationless Reciprocating Engine)

K. Ishida, S. Kanetaka, Y. Omori, and T. Matsuda
Faculty of Engrg., Fukui Inst. of Technology, Fukui, Japan, Bull. JSME, 20 (142), pp 466-474 (Apr 1977) 25 figs, 4 tables, 6 refs

Key Words: Reciprocating engines, Vibration control

Up to this day, known piston crank mechanisms used in various reciprocating internal combustion engines are inevitably accompanied with vibration, as the forces and moment caused by the inertia of the reciprocating mass are not balanced. Perfectly balanced rotation-reciprocation mechanisms can obviate or mitigate such disadvantages. This report relates to a gasoline engine utilizing an eccentric geared device of crank-shaft rotary motion system as the mechanism of motive power. Theories and experiments of this engine are described: that is -- vibration tests, various performance tests of this engine which is designed by the authors and manufactured on trial, are carried out.

77-1524

The Analysis of Structural-Vibration Related Noise

S. Kumar
Illinois Inst. of Technology, Chicago, IL., S/V, Sound Vib., 11 (4), pp 22-27 (Apr 1977) 6 figs, 17 refs

Key Words: Machinery components, Machinery vibration, Structural members, Noise generation, Statistical analysis, Correlation techniques

A systematic diagnostic approach for determination of the magnitude and nature of structural-vibration related noise generated by a machine or component has been developed. Quantitative estimates of noise produced by the vibrations of individual structural components are made by using statistical correlation theory. Success of this cross-correlation technique has been illustrated by its application to a large diesel engine. An analysis of both the acceleration of vibrating components and the noise produced, illustrates how it can be used to examine the contribution of structural vibration to the total noise field.

ROAD

(Also see Nos. 1440, 1465, 1477, 1478, 1490, 1506)

77-1525

The Overland Vertical Plane Dynamic Response of the AALC JEFF (B) AVC; Model Experiments

D.D. Moran
Performance, Dept., David W. Taylor Naval Ship Res. and Dev. Center, Bethesda, MA., Rept. No. SPD-615-04, 64 pp (June 1976)
AD-A035 846/5GA

Key Words: Surface effect machines, Surface roughness, Dynamic response

The overland dynamic behavior of an air-cushion-supported vehicle is investigated. Experiments have been performed by running the craft over repeated rigid wave forms and allowing it to pitch and heave. Transfer functions relating response variables to the excitation variables are presented. The linearity of the vertical plane dynamics is investigated through a comparison of the response for two different wave heights. Variations in fan speed and fan discharge are also examined. The cobblestone effect, created by exciting the craft at a very high frequency, is investigated.

77-1526

A Study of the Response of a Double Bottom Vehicle to Steering and Braking

J.R. Ellis and P.L. Read
School of Automotive Studies, Cranfield Inst. of Technology, Cranfield, UK, Vehicle Syst. Dyn., 5 (4), pp 205-219 (Dec 1976) 5 figs, 4 refs

Key Words: Articulated vehicles, Steering effects, Braking effects

The paper describes the development, operation and some of the results obtained from a simulation of the steering behavior of the double bottom articulated vehicle, in particular the effects that arise when certain axles are locked.

77-1527

Performance Evaluation of the NHTSA Advanced 'S' Series 50th Percentile Anthropomorphic Dummy. Volume I - Technical Report

D.E. Massing and P.E. Yates

Calspan Corp., Buffalo, NY, Rept. No. CALSPAN-ZS-5778-V-1, DOT-HS-802 073, 293 pp (Nov 1976) (see also Vol. 2, PB-263 650)

PB-262 672

Key Words: *Collision research (automotive), Experimental* data, Anthropomorphic dummies

The two series anthropomorphic test dummies were experimentally evaluated to determine the degree of conformance to specifications for dimensions, segment weights, and joint range of motion, to compare measured component static and dynamic characteristics to requirements, and to establish by sled testing in typical restraint and crash environments their experimental repeatability.

77-1528

Performance Evaluation of the NHTSA Advanced 'S' Series 50th Percentile Anthropomorphic Dummy. Volume II - Accelerator Sled Test Data

D.E. Massing and P.E. Yates

Calspan Corp., Buffalo, NY, Rept. No. CALSPAN-ZS-5778-V-2, DOT-HS-802 074, 518 pp (Nov 1976) (see also Vol. 1, PB-262 672)

PB-263 650/4GA

Key Words: Collision research (automotive), Experimental data, Anthropomorphic dummies

Four sled test configurations were employed to evaluate the dynamic performance repeatability of the NHTSA 'S' Series dummy. Type-2 belt, preinflated air bag, energy absorbing steering column, and Type-1 belt with simulated instrument panel test environments were utilized to measure the performance of two identically fabricated dummies. In addition, tests of a Part 572 dummy with Type-2 belts were performed to establish a control data set for the configuration. The graphical results of a statistical analysis performed on the results obtained from replicate tests of each configuration are presented.

ROTORS

(Also see Nos. 1419, 1445)

77-1529

Minimizing Assembly Imbalance in Turbomachine Rotors Made with Toothed Couplings: Locating Component Mass Centers

J.K. Davidson

Arizona State Univ., Tempe, AZ, J. Engr. Power, Trans. ASME, 99 (2), pp 189-194 (Apr 1977) 5 figs, 3 refs

Key Words: *Turbomachinery, Rotors, Balancing techniques*

A method is presented for locating component mass centers in turbomachine rotors made with toothed couplings. The geometrical relationships that would permit the assembly of a turbomachine rotor with predictive knowledge about component mass center locations and thereby have more specific knowledge on rotor mass distribution than is now available are described. Components are modeled both with one and with two lumped masses. The method requires individual component balance and measured residual imbalance.

77-1530

Shock Wave and Flow Velocity Measurements in a High Speed Fan Rotor Using the Laser Velocimeter

D.C. Wisler

Advanced Turbomachinery Aerodynamics, Aircraft Engine Group, General Electric Co., Cincinnati, OH, J. Engr. Power, Trans. ASME, 99 (2), pp 181-187 (Apr 1977) 13 figs, 13 refs

Key Words: Rotors, Fans, Shock waves, Measurement techniques, Lasers

The laser velocimeter, an instrument capable of making nondisturbing gas velocity measurements, was used to determine shock wave locations and to make gas velocity measurements within the rotating blade row of a 550-m/s (1800-ft/s)-tip speed fan rotor. The velocimeter measures the transit time of a seed particle across interference fringes produced at the intersection of a split and crossed laser beam. The rotor flowfields were obtained at several radial immersions for operating-line and near-stall throttle settings.

SHIP

(See Nos. 1421, 1422, 1423)

STRUCTURAL

77-1531

Fly-Shuttle Loom Noise

W.L. Eckert, E.T. Booth, J.R. Bailey, and P.D. Emerson

North Carolina State Univ., Raleigh, NC, Mech. Engr., 99 (4), pp 40-43 (Apr 1977) 7 figs, 10 refs

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SHIP

(See Nos. 1421, 1422, 1423)

STRUCTURAL

77-1531

Fly-Shuttle Loom Noise

W.L. Eckert, E.T. Booth, J.R. Bailey, and P.D. Emerson

North Carolina State Univ., Raleigh, NC, Mech. Engr., 99 (4), pp 40-43 (Apr 1977) 7 figs, 10 refs

Key Words: Textile looms, Noise generation

Fly-shuttle loom noise is one of the most significant problems now confronting the textile industry. A two-phase experimental program to identify sources of noise in a fly-shuttle loom is described. Sound pressure waveforms radiating from the loom are assembled. High-speed motion pictures were taken to correlate specific events in the loom cycle with impacts occurring in the waveforms.

USEFUL APPLICATION

77-1532
New Designs Through Vibration Welding
J. Mengason
Branson Sonic Power Co., SAE Paper No. 770235, 9 pp, 19 figs, 5 refs

Key Words: Vibratory techniques, Welding

A new plastics assembly technique has been developed which offers new opportunities in product design and assembly as well as new solutions to existing problems. This method, based on friction welding, overcomes many limitations of conventional welding processes such as part size, shape, material and speed of operation.

77-1533
Vibration Technique Joins Large, Complex Plastic Components
Product Engr. (N.Y.), 48 (5), pp 64-65 (May 1977)

Key Words: Vibratory techniques, Welding, Welded joints, Plastics

The technique for leak-proof joining of large plastic parts of complex shape, called vibration welding, is described. The principle is fairly simple: sufficient frictional heat is generated to melt thermoplastics by pressing the two plastic parts together and vibrating them through a small displacement in the plane of the joint; displacement can be in either of two modes, linear or angular.

77-1534
Frozen Soil Cutting Using Vibratory Blades
R.T. Burton and P.R. Ukrainetz
Dept. of Mech. Engrg., Univ. of Saskatchewan, Canada, SAE Paper No. 770546, 12 pp, 10 figs, 1 table, 12 refs

Key Words: Construction equipment, Vibratory tools

In many parts of the world, the working season of certain operations is severely limited due to winter freeze-up. This is essentially true in such areas as earth moving and trenching. These limitations are due, in part, to the large drawbar forces which act on the cutting machine as it is drawn through the frozen soil. Reducing this force by oscillation of the cutting tool as it passes through the soil is discussed.

AUTHOR INDEX

CALENDAR

MEETING	DATE	LOCATION	CONTACT
	1977 AUG		
Society of Automotive Engineers 1977 West Coast Meeting	8-11	Vancouver, Canada	SAE Hq., A. L. Weldy
	SEPT		
Vibrations Conference, ASME	26-28	Chicago, IL	ASME Hq.
	OCT		
NOISE-CON 77	17-19	Hampton, VA	Conf. Secretariat, Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie, NY 12603 Tele. (914) 462-6719
48th Shock and Vibration Symposium	18-20	Huntsville, AL	H. C. Pusey, Director, The Shock and Vibration Info. Ctr., Code 8404, Naval Res. Lab., Washington, D.C. 20375 Tele. (202) 767-3306
	NOV		
Winter Annual Meeting, ASME	Nov 27-Dec 2	Atlanta, GA	ASME Hq.
	DEC		
Sixth Turbomachinery Symposium	6-8	Houston, TX	Dr. M.P. Boyce, Gas Turbine Labs., ME Dept., Texas A & M, College Station, TX 77843
Acoustical Society of America, Fall Meeting	13-16	Miami Beach, FL	ASA Hq.
	1978 MAR		
Applied Mechanics Western and J.S.M.E. Conference	25-27	Honolulu, Hawaii	ASME Hq.
	APR		
Design Engineering Conference & Show, ASME	3-5	Chicago, IL	R.C. Rosaler, Rice Assoc., 400 Madison Ave., N.Y., NY 10017
Gas Turbine Conference & Products Show, ASME	9-13	London	ASME Hq.
Diesel & Gas Engine Power Conference and Exhibit	Apr 30-May 4	San Francisco, CA	ASME Hq.

CALENDAR

MEETING	DATE	LOCATION	CONTACT
	1978 MAY		
Inter-NOISE 78	8-10	San Francisco, CA	INCE, W.W. Lang
IX Southeastern Conference on Theoretical and Applied Mechanics (SECTAM)	4-5	Nashville, TX	Dr. R.J. Beil, SECTAM, Dept. of Engrg. Sci. & Mech., Virginia Polytechnic Inst. & State University Blacksburg, VA 24061
Offshore Technology Conference	8-11	Houston, TX	SPE, Mrs. K. Lee, Mtgs. Section, 6200 N. Central Expressway, Dallas, TX 75206
Society for Experimental Stress Analysis	14-19	Wichita, KS	SESA, B.E. Rossi

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS:	American Federation of Information Processing Societies 210 Summit Ave., Montvale, N.J. 07645
AGMA:	American Gear Manufacturers Association 1330 Mass. Ave., N.W. Washington, D.C.
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, N.Y. 10019
AIChE:	American Institute of Chemical Engineers 345 E. 47th St. New York, N.Y. 10017
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, Ill. 60605
AHS:	American Helicopter Society 30 E. 42nd St. New York, N.Y. 10017
ARPA:	Advanced Research Projects Agency
ASA:	Acoustical Society of America 335 E. 45th St. New York, N.Y. 10017
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, N.Y. 10017
ASME:	American Society of Mechanical Engineers 345 E. 47th St. New York, N.Y. 10017
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, Ill. 60202
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, Wis. 53203
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, Pa. 19103
CCCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada
IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, N.Y. 10017
IES:	Institute Environmental Sciences 940 E. Northwest Highway Mt. Prospect, Ill. 60056
IFToMM:	International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME, Amherst, Mass. 01002
INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch, Poughkeepsie, N.Y. 12603
ISA:	Instrument Society of America 400 Stanwix St., Pittsburgh, Pa. 15222
ONR:	Office of Naval Research Code 40084, Dept. Navy, Arlington, Va. 22217
SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, Pa. 15096
SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, England
SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, Conn. 06880
SNAME:	Society of Naval Architects and Marine Engineers, 74 Trinity Pl. New York, N.Y. 10006
SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375
URSI-USNC:	International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, Mass. 02173